Chapter Five

Loss of Control Event (LCE) investigations

Billy said, 'man pull a boat up a hunnerd time, one time he fall down the bank. Jus happen like that'. 'Jus happen like that? Inchebe repeated scornfully, 'tell me one ting, you soso clever. Why it happen this partikkler mornin?'

Barry Unsworth. (1992). Sacred Hunger.

5.1 Introduction

The aims of the study reported in this chapter were to:

i. Develop a suitable investigative method for the analysis of quadbike LCE on New Zealand farms
ii. Identify risk factors for LCE and their interactions
iii. Identify potential interventions that would reduce the incidence and/or severity of quadbike-related LCE on New Zealand farms.

An ancillary aim was to also compare the characteristics of the LCE on New Zealand farms with those reported in North America to assess whether or not the practice of transferring intervention ideas between the two was supported by the evidence bases.

The literature review and epidemiological study reported in the previous chapters provided a gross perspective on the scale and direct costs of quadbike LCE on farms. These studies also offered broad indicators as to the nature and context of the events. From the findings of these earlier chapters, and the incident-independent data presented in Chapter Four, it was concluded that the contexts of use and patterns of incidents differed too much between New Zealand and North America for the adoption of interventions without more detailed investigation of the specific events on New Zealand farms.

The research reported in this chapter is therefore a nationwide study of incident-centred investigations (n=156) conducted in 2002, on 53 farms spread through 13 of the 15 census regions of New Zealand. A systems approach was adopted, and the resulting method drew from a number of relevant areas of the incident investigation literature notably: slips, trips & falls, road traffic and aviation. Scale models of quadbikes and common implements were used to assist the subjects in recalling and explaining event sequences in the LCE. Details of the events, risk factors and potential interventions were captured on a hybrid event sequence chart that was developed as part of this study.

Previous studies in New Zealand on quadbike Loss of Control Event (LCE) had been limited to postal or telephone surveys (OSH, 1998), or had not included task factors relating to the event (Brown, 1998). Brown's 1992 research in Southland published six years later, had also been based on a checklist of 57 predetermined factors derived from a previous, unpublished study by the author.

This study therefore sought to investigate contemporary quadbike-related LCE scenarios and potential interventions in-situ, within the work system, and without pre-determined factor categories or category limits. Specifically, by identifying patterns in LCE, with respect to rider/individual factors (employment status, exposure, age and sex distribution, injuries by type and body region, degree of isolation at the time); temporal factors (time of day, time of year); terrain/ground factors and task-related factors (task/activity immediately preceding the incident, ancillary implements in use, injury agency); injury mechanisms, event sequences and risk factors for major activity categories and serious injury LCE cases.

Potential interventions developed during the study are discussed. Firstly, the study considers interventions that apply pre-LCE (primary), followed by those acting during LCE (secondary) or post-LCE (tertiary).

5.2 Background and theoretical approach

It is widely agreed in the literature that events such as quadbike off-road LCE generally involve a complex variety of interacting factors at multiple levels (Hollnagel, 2005). This approach of addressing the system as a complete entity has been well established as a pragmatic response to reductionism for at least three decades (Beishon & Peters, 1972).

Interactive models of injury causation see the human as an imperfect processor of information in continual interaction with their environment (Slappendel, 1995, p.240). An epidemiological approach, as adopted in Chapter Three, provides a useful country-wide overview of scale and cost, basic descriptive data and in some cases broad indicators of the event mechanisms (Bentley & Haslam, 2006), but intrinsically lacks crucial detail about both the environment and the interactions.

The aim of this incident-centred study was therefore to gain an understanding of the nature and context of quadbike LCE on farms, together with potential interventions, through investigating specific events with their unique sets of interacting risk factors.

The literature review revealed no single existing method that would serve this purpose. In particular, it was noted that there was little published material on incident investigation methods for off-road activities or for cases where the investigation was conducted some weeks or months after the incident. The method developed in this research, therefore, built on a number of established techniques and models, modified by findings from research in related fields. The preparation for this aspect of the study included a review of issues in event recall and potential investigative techniques in related disciplines, not only via the literature but also through personal interviews with practitioners in air accident investigation at New Zealand Civil Aviation, and the Royal New Zealand Air Force. The following section is a discussion on pertinent recall issues together with contributing incident investigation techniques and models.

5.2.1 Causation theories

"The identification of causes is very much a perceptual process ... guided by his or her own frame of reference ... [which is] constructed through exposure to policy statements, practical experience and formal theories of accident causation" (Slappendel, 1995). The use of agreed theoretical structures therefore provides a more consistent framework and perspective for investigations than relying solely on the professional homogeneity of the researchers.

A wide array of causation theories and models has been proposed during the last century. Some, such as the Pure Chance Theory – described by one practitioner in the USA as "not so much a theory as a system weakness in itself', have been discredited. The strategy of simply weeding out those appearing to be 'Accident Prone' has been similarly found wanting; Kletz (1990), for example, pointed out the fundamental weaknesses in the statistical arguments used to support this principle.

This section contains a brief discussion on those with some bearing on this study of quadbike LCE on New Zealand farms; either as potentially useful method components, or for historical context.

5.2.1.1 The Domino Theory

Although other theories had been widely proposed prior to Heinrich's (1941) 'Five Factors in the Accident Sequence' Domino Theory, this was the first that had a substantial impact on New Zealand industry (Slappendel, 1995). According to this theory, accidents (domino four) and the subsequent injuries (domino five) come about as result of domino one - Ancestry (inherited traits) or Social Environment (bad company); domino two – Fault of the Person (recklessness, violent temper, ignorance etc); domino three – the Commiting of Unsafe Acts or the Presence of a Mechanical or Physical Hazard (horseplay, standing under loads, removal of guards, etc).

Heinrich's view was that not much was to be gained by managers looking for underlying causes, as they had little opportunity to influence factors outside the workplace. The Unsafe Acts should be the focus, he suggested, and supported this by the reporting in the 1959 edition of a single study of 75,000 incident cases from insurance records and company documentation. This suggested that 88% of all these could have been avoided by preventing the unsafe acts of persons, and a further 10% by addressing unsafe conditions. Slappendel (1995, p. 218) notes that his analysis recognised multiple factors to be present in some cases, but that these findings were overlooked, with only a single immediate cause reported.

Between 1958 and 1974 the Domino Theory was taught in New Zealand using the Lateiner Method of Accident Control for Supervision, and over 26,000 people attended. Perhaps due to the simplicity with which the domino theory places the onus for change precisely where management are most comfortable with it – on supervisors and the supervised, aspects of Heinrich's work have remained popular in some circles. Nearly half a century later the '88% unsafe acts' figure (rounded to 85:15) is still being quoted by behaviour-based training organisations in New Zealand.

The terms unsafe acts, and unsafe conditions also survived and continue to be used on the incident report form in many workplaces even today. Brown (1990), an OSH inspector from Southland, in his study of ATV incidents noted that their use in Department of Labour investigations at that time resulted in the failure to identify even a minority of the possible factors involved, gave no indication of the underlying reasons for the worker's actions, and lead to a preoccupation with possible mechanical causes. His study recommended the use of a simplified version of Accident Review Tree Trunk Method as used at the local smelter in Bluff, which identified essentialfactors – without which the injury would not have been sustained, and also the contributingfactors. With this method, these factors are still, however, recorded as individual contributors – rather than as part of an interacting set.

This analysis method was still in favour (personal communication) at ACC amongst Agriculture injury prevention staff at the commencement of these quadbike studies in 2002.

5.2.1.1.1 International Loss Control Institute (ILCI) Loss Causation Model

Also known colloquially in New Zealand as the New or Updated Domino Theory, the ILCI model was introduced in the 1970s and built on the work of Heinrich. The five dominos remained, but the model addresses a weakness of the original with Lack of Management Control replacing Ancestry as the underlying cause on the first domino. Multiple factors for individual events, rather than single immediate causes, are also recorded - under the titles of either human factors or job factors. However, as Slappendel (1995. 228) points out, this separation of the factors still dismantles the elements of the event, discarding, the possibly critical, interactions.

5.2.1.2 Epidemiological models

Developed originally for applications in infectious disease control, the epidemiological model considers an equilibrium of three elements: host (the human), the agent (the disease) and the environment (biological, social and physical). Change in any one of the three will increase or decrease the incidence of the disease. When applied to vehicle incidents the agent is replaced by the term ***energy exchange.***

Of specific relevance to this study of off-road vehicle incidents is the work of epidemiologist and Public Health Physician William (Bill) Haddon. His papers on injury prevention have proved influential and continue to be widely cited (Baltimore, 2002). His work (1968) presented a basic matrix for plotting potentially modifiable factors as shown in Table 5.1 for pre-crash, in-crash or post-crash phases of road traffic incidents.

Table 5.1 Basic Haddon matrix

Environment			
Vehicle			
Human			
	Pre-crash	**In-crash**	**Post-crash**

Haddon developed the matrix further (Haddon, 1970; Haddon, 1972) adding to and modifying the categories in the vertical axis to allow the capturing of a greater variety of risk factors and potential countermeasures. He and other epidemiologists countered criticisms of their high-level approach by asserting that a detailed knowledge of the event mechanisms was not needed for intervention design; injury prevention activity could be 'decoupled' from a full understanding of the processes of causation (Slappendel, 1995). This was to be achieved by the placing of 'defences' between host and agent. Haddon used the example of insulation and guards on electrical components that prevent electrocution irrespective of the reasons why people came into contact with them. The Haddon '10 Countermeasures List' (1973) shown in Table 5.2 summarised his strategies for placing such defences.

Table 5.2 Haddon 10 Countermeasures list

Pre-Crash	1. **Prevent marshalling of initial form of energy.** 2. **Reduce amount of energy marshalled.**
Crash	3. **Prevent release of energy.** 4. **Modify rate of spatial distribution of energy from its source.** 5. **Separate in time or space energy released and susceptible structure.** 6. **Separate them by material barrier.** 7. **Modify the damaging contact surface.** 8. **Strengthen living structure susceptible to damage.**
Post-Crash	9. **Move rapidly in detection and evaluation, limit damage extent and spread.** 10. **Rehabilitation.**

The Haddon matrix continues to be widely used in modified forms in other spheres including aviation (O'Hare, Chalmers & Scuffham, 2000; Chalmers, David, O'Hare, McBride, 2000) and road traffic motorcycle accident investigations (Organisation for Economic Co-operation and Development [OECD], 2001).

The Haddon 10 countermeasures list could be seen to intimate multiple intervention possibilities at various points in the event chain, but that does not appear, however, to fit with the epidemiological model. Culvenor (1996) argues for a de-coupled approach with prevention efforts targeted at the source. A potential weakness of this model for quadbike LCE analysis and injury prevention is that the model assumes that there is always a single identifiable Source (rather than a set of interacting factors at various system levels), and that it can be acted at without needing to understand the more distal mechanisms of causation.

5.2.1.3 Human error models

'People make accidents, but organisations cause them'
(Wagenaar, 1998).

By contrast to agriculture, some industries, including aerospace and petrochemicals, are reported to have done well in systematically reducing unplanned losses, and human error models are commonly employed in these sectors. Since the 1960s, pilot fatalities in non-combat situations have reduced by a factor of 50 (Wiegman & Shappell, 2003, p. 5), which the authors attribute to various system improvements including enhanced investigative and predictive tools. Central to this according to Wiegmann & Shappell, Strauch, (2002) and many others, is the work of Reason, Wagenaar, Hudson and others (Reason, 1990; Wagenaar, 1990; Wagenaar, Groeneweg, & Hudson, 1994) which has shifted attention away from the worker and onto the more distal factors of company policy and management decisions. The concept of Latent Failure, originally developed for nuclear power systems and refined, so to speak, within the oil industry TRIPOD programme (Wagenaar, 1994) acknowledges the role of skill or rule-based failures (Rasmussen, 1982) at individual human level, but traces the error-enforcing conditions for these back to an organisational level. Their work starts from the assumption that the substandard acts of individuals can be anticipated and modified by addressing the environmental conditions that elicit these. Wagenaar (1998) believes that human behaviour in an occupational setting "is lawful and predictable; not 100%, but to such a large extent that it is useful for injury prevention".

Charlton (2002) explains the individual level errors as being of three types. Mistakes – which are unintentional and due to ignorance; lapses – which are unintentional and due to people operating 'on automatic'; and violations – which are the intentional breaking of rules because they are perceived to 'cost' too much to obey. He argues that we should design systems that are tolerant of unintentional errors, and not too 'costly' to obey.

The detailed work by Wagenaar, Reason and others in the oil industry on the TRIPOD project produced the investigative and predictive tools based on a set of nine 'general failure types' (GFT). In the field, this GFT template is used in investigations (termed a reactive application by the authors) to plot causes, and in a proactive approach to capture audit data from the organisation and thereby profile areas of system weakness. Within a specific industry sector, the authors are satisfied that the interplay of these two applications of the GFT system over time has resulted in a systematic, predictive tool with genuine value to management.

There are, however, weaknesses of the GFT system as a tool for investigating quadbike LCE on New Zealand farms. The system was devised as a tool to provide a safety strategy for a highly regulated, multinational, largely homogenous, intensely hierarchical industry. The 80,000 farms in New Zealand employ on average 1.5 people each and so some conceptual incompatibility is to be expected. There is certainly potential for the model to be used at a gross, industry-wide level, as a checklist for identifying long term intervention needs, but at single farm level it does not appear sensitive enough to accommodate either the wide contextual variety found, nor the risk factor interactivity.

A survey by Hollnagel in 1993, cited by James Reason in the Foreword to Strauch (2002), tracked the human factors literature for three decades and found that erroneous individual actions accounted for 20% of incidents in the 1960s but 80% in the 1990s. This study, which was achieved with secondary and tertiary data, conflicts with other early papers (e.g. Feggetter, 1982) that put the human error contribution higher, but the authoritativeness of these studies has to be questioned as well. Reason attributes the apparent change to the vast improvement in electronic and mechanical systems over this time, and uses this as a justification for focussing less on non-human aspects of the system. While farming has indeed enjoyed these advances in principle, they may not have had the impact that they have had in other industries. Firstly, farm machines are not custom-designed, replaced as often or looked after as an aircraft or power generator in a wealthy country would be. There remains negligible third party inspection or regulation as the findings in Chapter

Four showed. Whilst productivity per hectare and per worker has risen significantly in this country, overall human wellbeing on farms here and worldwide has improved far less. In the USA, Schenker (1996) reports that statistics for non-fatal cases seen since the 1970s in the other 'hard' industries – mining and construction had improved, but that agriculture resisted the trend. In 1996 UK fatalities in agriculture were noted as having remained 'remarkably consistent' (O'Neill, 1999). Agriculture may not have stood entirely still since the 1960s but any gains made in mechanical assistance and reliability might have been lost through the estimated 40,000 deaths worldwide each year now attributed to contact with pesticides (Myers, 1998). On the basis of these trends it would be unwise to assume that in New Zealand agriculture the quadbikes are intrinsically reliable and safe. Agriculture will also have under-represented in Hollnagel's study as there have been very few such human factors research papers published - in comparison to those from the military and multinational-dominatedindustries.

It would be possible to plot all contributing risk factors found from the LCE around New Zealand on a GFT graph under the headings (hardware, design, maintenance, operating procedures, error-enforcing conditions, housekeeping, incompatible goals, communication, organisation), but a great many would probably be found in an industry where there are few strict operating systems; tasks involving quadbikes and animals on changeable terrain are rarely 'well-rehearsed routines or schema' (Wagenaar, 1994). The height of columns alone would not necessarily assist in predicting the likelihood of an LCE. The Failure State Profiling also does not identify critical risk factor combinations or factor interactions.

The pilot work for the current investigations indicated that vehicle incidents in a dynamic environment such as this are very rarely the result of a single variable changing. To quote Loppinet and Aptel (1997), it is not "a model where a (single) cause produces an effect but [it is within] a probability frame in which multiple factors interplay, occupational factors, but equally those external to an occupation."

The reconstruction of mindset begins not with the mind.
It begins with the circumstances in which the mind found itself.
(Dekker, 2003)

Dekker presents an information processing approach to the study of Human Error in flight systems (Dekker, 2002), which appears relevant to this study of quadbike LCE. He suggests that the investigator needs to gain an understanding of why the assessments and actions of the pilots made sense to them at the time, given the circumstances that surrounded them. In none of the ACC quadbike cases reported in Chapter Three was there any intimation of intentional self harm, and so we must assume that maiming by quadbike is not a popular means for those inflicting self-harm. They may have believed their decision to be increasing risk but they still didn't believe it would result as it did – or they wouldn't have done it. As Perrow (1999) observes, "patient accident reconstruction reveals the banality and triviality behind most catastrophes."

5.2.1.4 Interactive Models

'Because every factor interacts in a social system, because every-thing, every property, every relation is therefore in a state of mutual dependence with everything else, ordinary cause-and-effect analysis of events is rarely possible. In fact, it is nearly always grossly misleading..'
(L.J. Henderson, from his Sociology 23 Lectures 1941. Published in: Barber, 1970. p28)

In interactive models the human is seen as an imperfect processor of information in continual interaction with their environment (Slappendel, 1995).

The interactive model shown in Figure 5.1 was developed by Slappendel for use by the forestry industry in New Zealand. It draws on several earlier interactive models including Wigglesworth's Model of Injury Causation (Wigglesworth, 1972, p. 74); Hale and Glendon's Behaviour in the Face of Danger Model (Hale & Glendon, 1987, p. 31); Petersen's Accident-Incident Causation Model (Heinrich et al., 1990, p. 49); and DeJoy's Human Factors Model of Workplace Accident Causation (Dejoy, 1990).

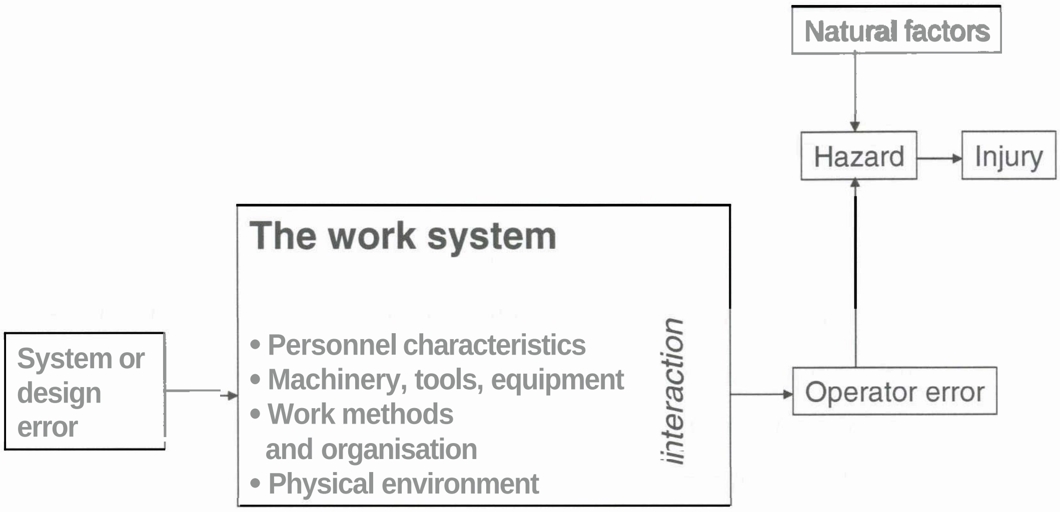

Figure 5.1 Model of Injury Causation for Forestry Work.
(Redrawn from Slappendel, 1995, p. 241).

According to Slappendel, the model suggests that hazards can be introduced in three different ways. Firstly, system or design errors remote in time or space from the injury, and which are made by people such as designers and managers. These include fundamental weaknesses in the design of the equipment, for example, poor vibration control in chainsaws, or high management errors in policy setting or priorities.

The second source of error in this model is via cognitive lapses by the operator. The example given is that of a worker who notices but decides to leave a fallen tree dangerously lodged against another one (a hang-up) - poised to drop on another worker at some point. These operator errors are shown as outputs of the four interacting sets of factors in the Work System. 'The interaction is critical, as errors are more likely to occur if there is a major mismatch between the components'.

A more recent model proposed by Bentley (submitted) developed for applications concerning slip, trip and fall (STF) events and adventure tourism safety analysis, is shown in Figure 5.2. This builds an the interactive approach of Slappendel and others but makes explicit the information processing element derived from the work of Ramsey (1985), and Hale and Glendon (1987). Importantly, this model acknowledges that in workplace incidents the individual has to not only perceive the hazard, but also recognise it as such, formulate an effective plan to avoid it, and have the ability to execute that plan in the time available. This information processing element is clearly relevant in a quadbike LCE context where the attention of the rider may well be drawn away from the terrain ahead, and subsequent - possibly catastrophic events, can happen at speed.

As with the earlier interactive models, a hazardous situation is generated through interactions involving latent, natural and/or active factors. The two-way arrows between the environmental factors and the management factors indicates the role that senior staff have in planning for safe operations throughout the year, as far as is possible, taking into account the predicted extremes of weather. The model indicates that in some cases these largely uncontrollable factors will lead directly to unsafe behaviours or actual injury risk irrespective of who the individual is. Presumably the presence of black ice on unlit steps for example.

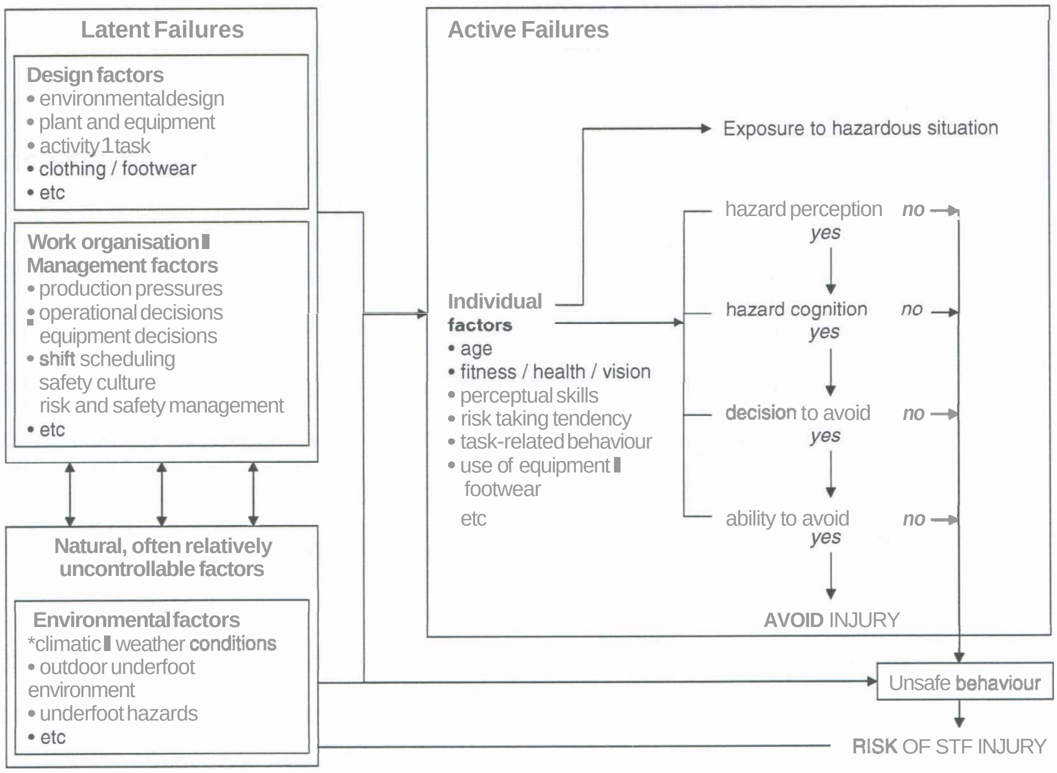

Figure 5.2 An information processing model for STF analysis. Redrawn from Bentley (submitted)

The latent factors in this model also act on the information processing sequence after initial perception. Having seen and understood a hazard, the individual may choose not to avoid it, but instead to take a risk. The example given is the decision to proceed to walk quickly on a slippery surface, knowingly increasing the risks of a STF, but judging it an acceptable trade-off for saving time or effort. Factors taken into account at this point may include 'organisational behaviour-shaping factors' such as delivery target times that did not allow for snow and ice on the roads, and job-and-finish policies (Bentley & Haslam, 2001) that encourage compression of the working day.

Slappendel (1995, p. 243) notes that although the ergonomics systems approach has gained general support in New Zealand, uptake has been less widespread in practice. Out in the field, 'almost all sense of interaction (is lost) as soon as they start using the simple classifications and tick-box formats'. These checklists ostensibly derived are more user-friendly and require a lower level of operator training – but an ergonomics systems approach is effectively abandoned. The gulf between the theoretical understanding of workplace incident causality as displayed in the literature, and the methods by which industry analyses incidents continues to grow in New Zealand for the lack of suitable field techniques, Slappendel suggests.

5.2.2 Problems with recall of events

"You don't write the truth, you just write what people say...you don't come across the truth that easy."
Kurt Luedtke (1998) from the film 'Absence of Malice'.

A limitation in this study is that the quadbike LCE follow-up investigations had to be carried out well after the events took place. This was due to the necessary process of identifying and recruiting subjects via ACC claimant records. In many cases the LCE was already two weeks or more old when the person concerned presented at the doctor's clinic. Following this were several more weeks of claim administration before the data appeared on the database. The most recent LCE cases provided by ACC were therefore two-to-three months old. This delay was not seen as problematic by some involved in the pilot study, for as one seriously injured farmer stated "you don't forget any details of something that hurts that much". The literature however indicates that although vivid, such impressions may not even be accurate to start with, and will become increasingly unreliable with time (Baddeley, 1999).

All investigative analyses however, whatever the delay, are by definition retrospective and subject to some loss of recall accuracy or detail as well as being subject to potential sources of bias - such as attribution error, whereby the reasons for individual behaviour are attributed by the injured person to external (environmental) factors. While delay minimisation was therefore desirable, not least to maximise the presence of material evidence, some of the challenges faced in designing a method for this LCE study were also found in other forms of investigation.

'Remembering is not the re-excitation of innumerable fixed, lifeless and fragmentary traces. It is an imaginative reconstruction, or construction built out of the relation of our attitude towards whole active mass or organised past reactions or experience, and to a little outstanding detail ...It is thus hardly ever really exact, .. and it is not at all important that it should be so.' Sir Frederick Bartlett (1961).

From a purely academic point of view the above quote may be true, but in courtrooms and at crash scenes it is clearly important that as clear an understanding of the actual events and contributing factor interactions are gained as possible. Memories of events - what happened where and when - are thought to be stored in different ways from facts. Episodic memory contains our recollections about all the things that have happened to us or that we have witnessed, whereas semantic memory holds basic facts about our knowledge of the world (Baddeley, 2002; Tulving, 2002).

Confusion and inflation of details about such events are reported to grow stronger with lapsed time (Garry, Sharman, Wade, Hunt & Smith, 2001); and this is believed to be especially true for those subjects with a good imagination (Garry & Polaschek, 2000). Not only does delay reduce the likely accuracy and completeness of the accounts that may be obtained though, but it also reduces the availability of objective evidence for triangulation.

Discussions with Massey University Historians suggest that there is (surprisingly) little research activity in recall accuracy in the Oral History field, but psychologists working with the legal system have conducted significant amounts of work in the area of memory reliability (Loftus, 1996; Loftus & Ketchum, 1991) and bias specifically related to risk assessment (Moore, 1996).

The steps involved in compiling and recalling details of events according to Loftus & Ketchum (1991) are shown in Figure 5.3.

Figure 5.3 Key steps in Event Recall (adapted from Loftus & Ketchum, 1991)

Acquisition			**Retrieval**	
Original experience		**Subsequent information**		
1. Decision of what to look at.	**2. Integration into a representation**	**3. Integration of new information into an altered representation**	**4. Regeneration of the altered representation**	**5. Response**
Time →				

The literature suggests that there are a number of ways in which inaccuracies can be introduced, most notably by starting with an incomplete impression and subsequently filling in the gaps to make a plausible whole when recounting later. The new, but inaccurate ideas may also be introduced through bias from leading questions immediately post-event referred to as the Misinformation Effect (Loftus & Ketchum 1991).

> "Memories don't just fade, as the old saying would have us believe; they also grow. What fades is the initial perception, the actual experience of the events. But every time we recall an event, we must reconstruct the memory, and with each recollection the memory may be changed - coloured by succeeding events, other peoples' recollections or suggestions, increased understanding, or a new context." (Loftus & Ketcham, 1991)

Some of the types of data needed in this study are particularly likely to be inaccurately reported. For example the nature of critical surface changes or the source of visual distraction while riding the quadbike. As Bartlett (1961) notes, to recall, the subject first has to have perceived. He suggests that the eyes of the driver/rider are subconsciously drawn through 'expectation' towards those parts of the environment where they believe the most useful information will be for maintaining stability, course setting and detecting obstacles. Where the 'expectation' is wrong, or there is too much to process, recognition errors occur – the situation is wrongly interpreted. Subsequent recall of the event cannot therefore be complete and true as it was not perceived accurately in the first place. Noy (2001) reports that in a major USA study recognition errors were far more prevalent than either performance errors or poor driver decisions, definitely contributed to 41% of all traffic accidents, and probably involved in 56%. The implication of this for quadbike LCE investigations is that cross-verification of accounts is essential, even if the rider is convinced of their accuracy.

5.2.2.1 Optimising recall

In developing the method for the collection of the data from the field, key literature on memory was therefore reviewed, firstly to gauge the likely source, extent and nature of the inaccuracies in recall that should be expected, and secondly to establish what could be done to optimise recall. There was nothing found in the literature on investigations in the occupational health and safety field, but relevant tools for improving the quality of eyewitness reports appeared to have been well established in forensic psychology sources for several years (Geiselman, 1988). Elements of these methods are now used in applications other than the criminal justice systems, under the title Cognitive Interviewing (Memon, Wark, Holley, Bull & Koehnken, 1997).

Site methods to assist with accurate and more complete recall include the provision of context-dependent cues (Smith & Vela, 2001). According to Tulving (1983), an early leader in episodic memory research, memory for material is enhanced when contextual stimuli encoded along with target information are present at retrieval. This Encoding Specificity principle suggests that surrounding the riders with as many cues as possible, including smell (Herz, 1997), that were present at the scene of their LCE will assist memory retrieval.

The New Zealand Police training resources (New Zealand Police, 1997) include the effects of shock on recall, for example the likelihood that those hurt will make mistakes in their perceptions of time. The need for corroboration is highlighted, especially where what is reported and what the researcher can see do not 'match up'. This echoes established conclusions from the Social Sciences. Webb, Campbell, Schwartz and Sechrest (1966), argue that multiple methods of investigation including Unobtrusive Measures are needed in social settings. "Interviews and questionnaires intrude as a foreign element into the social setting they would describe, they create as well as measure attitudes, they elicit atypical responses, they are limited to those who are accessible and will cooperate. But the main objection is that they are used alone. Interviews and questionnaires must be supplemented by methods testing the same social science variables but having different methodological weaknesses".

Recent evaluation studies on the effectiveness of Cognitive Interviews (Memon et al., 1997) suggests that the critical features of this group of techniques are that the interviewer achieves context reinstatement, uses imagery and encourages the subject to 'report everything – not screening out anything they consider to be irrelevant or of which they have only partial recall'.

The overall approach adopted therefore was to create a cue-rich situation where the subject had as many access 'routes' to the episodic memory of the events as possible, utilising the reinstatement effects of the environmental cues (Smith, 1988). The multiple route approach would also, it was hoped, allow sifting of the memory to reveal false traces introduced post-event that had been integrated and stored as fact

(Sevelj, 2003) by memory trace triangulation. The use of the scale quadbike models, for example, may enable some types of inconsistencies to be tested – 'I thought my leg was trapped like this, but it can't have been if the bike was like that'.
Where the weather or other factors made the exact location of the LCE inaccessible with loss of some environmental context-dependent reinstatement advantages, the interview was conducted using mental reinstatement (Smith & Vela, 2001), with the assistance of sketches, photos and the scale model props. In these cases the subjects were asked to show the researcher a piece of land with similar characteristics. While not as effective, studies had shown this to be a practical alternative for crime scene investigators under tight time constraints or where the scene had altered too significantly.

Memon et al (1997) also concluded from their research that when rapport and communication were improved between researcher and subject, significant gains in information quality can be achieved. In recognition of this, time allowances per interview were generous so that farm visits did not need to be rushed and any hospitality offered to the researcher could be accepted to foster a strong rapport. At most farms the data collection visits actually extended far longer than the subject had initially agreed to - due to the relationship established.

The procedures followed on site to optimise recall detail and accuracy in the LCE study include context-reinstatement, the use of props, participative graphic event charting, and evidence corroboration, are discussed further in section 5.3 Methodology.

5.3 Methodology

The LCE investigations were undertaken at the same farms, and during the same visits as the context studies reported in Chapter 4. The LCE studies were conducted first where time was limited by weather factors or the availability of the subjects. Selection of the farms was based on suitability of the LCE subject, rather than any criteria relating to the context study.

5.3.1 Sample design

No authoritative pre-existing data were available regarding quadbike usage and LCE on farms. The context study data that had already been gathered (reported in the previous chapter), therefore provided the most comprehensive description of farm quadbike use available at the time in New Zealand. The population to be targeted, sample sizes and regional representation were therefore discussed and agreed, using this data, in consultation with the Agricultural Industry Health and Safety Council and Massey University statistician Dr Denny Meyer.

The study sample was of users reporting injuries suffered while using quadbikes in agriculture or horticulture and included: farm owners, employees and working family members. Contractors were also included who, by definition, would probably not still be working on the same farm on which the LCE had taken place. Despite the limitations this placed on investigative methods, these were included in the study as they provide useful insight into a small but growing sub-population that are high-risk due to factors discussed in Chapter Four, including the intensive quadbike usage, lack of task variety and requirement to operate in remote and difficult areas.

New Zealand farming operations vary significantly, and these are primarily linked to the climatic zones. Within this small country there are sub-tropical, temperate, alpine and temperate rainforest zones. Regional representation was critical for face validity of the studies within the industry. The final design of regional sampling is shown in Table 5.3.

Table 5.3 Sampling by regional groupings

Study zone	Census regions included	LCE
1. **Upper North Island**	**Northland, Auckland, Waikato, Bay of Plenty, Gisborne**	**45**
2. **Lower North Island**	**Taranaki, Manawatu/Wanganui, Wellington, Hawkes Bay**	***55***
3. **South Island**	**Canterbury, Otago, Southland, Tasman, Marlborough**	**56**
	Total	**156**

156 LCE cases representing three national study zones were drawn from a combined sample pool of 724.

Approximately 5% of investigations attended by the researcher could not be conducted at all, or could not be completed. Most commonly this was due to the researcher discovering on arrival at the farm that either the subject was not available as arranged, or that the facts of the case were significantly different to the impression gained during the screening interview over the telephone. It was common for the account collected on site to differ markedly from the account provided on the ACC records. In some cases the LCE, as it actually appeared to have happened once the subject had relaxed and provided some corroboration, still met the criteria. In others it did not.

5.3.1.1 Recruitment

The sample of 724 cases from which the final set for investigations was drawn were recruited from two sources, the Accident Compensation Corporation (ACC) claims database and via a public appeal for subjects through the media.

Firstly the ACC database was searched for the period from July 2000 – Sep 2001 using keywords identifying claims involving quads. Over a thousand (1013) cases were produced and screened to identify those that listed agricultural or horticultural occupations at the time of the claim. This produced 634 claims. This method was expected to produce a population within which family members using quadbikes, and others who farmed as a secondary occupation, were under-represented.

A limitation of relying purely on the ACC database for subjects, identified in the findings of the context study in Chapter Four, was that there appeared to be reluctance by some self-employed farmers to register claims with this government insurance provider. Obtaining income-linked benefits was reportedly too protracted, and ultimately unsuccessful, and the injured parties either therefore absorbed the cost or used an alternative insurer such as Farmers Mutual. This group might have therefore been seriously under-represented without a secondary source of recruitment. Also under-represented in the ACC database, but accessible via public appeal, were those for whom farming was not their stated occupation, such as student family members and those with another job away from the farm. It is quite common for people in New Zealand who are attempting to get established in farming to be employed full time at their primary job but also working for at least 40 hours a week on their smallholding.

The second recruitment method therefore was via the use of a series of 20 press releases sent to the main local newspapers in each of the 16 regions, leading to national and local printed media and radio coverage of the quadbike LCE study. The final number of stories this generated is unknown due to the practice of syndicated publishing – the press releases were relayed electronically over a number of intranet systems.

The project was introduced in the following way. 'We are looking at why people come unstuck with quads so much, and what can be done about it - so that other families don't need to suffer the way that yours have'. The wording was developed in conjunction with South Island Radio Journalist Nadine Porter following a live interview on air with the researcher broadcast in the South Canterbury district (FOX FM Ashburton, 10/10/02). She had found that farming people in her region would most readily come forward and talk about their own problems if it was going to achieve something for others.

Readers were invited to call an 0800 (freecall) number and leave their details with research secretaries at Forest Research offices in Rotorua. A screening interview was held by telephone within 36 hours, conducted by the researcher. The Information Sheet formed the schedule for the interview and comprised: introduction to the study and its aims, affiliations of the researcher, relationships to the funders and to Massey University, confidentiality provision. In addition the potential subject was also asked for details on geographical region and recency of the LCE being reported. Finally, the incident in question was discussed, in order to establish that it complied. As noted elsewhere, the accounts recorded in the ACC data rarely matched the verbal descriptions, and in 10-15% of cases bore no resemblance whatsoever. In total 90 individuals, not included in the ACC dataset, were added to the pool.

5.3.1.2 Recency

It was required that subjects had experienced an LCE within the previous two years.

5.3.1.3 Severity

Minimum severity of injury outcome was not stipulated. This was influenced by the finding during the piloting that inter-personal differences in reporting were substantial. An injury considered not worth mentioning by one person maybe very significant to another. Greater objectivity through triangulation with other sources (viewing medical records, checking with family members etc) on the telephone was impractical, and indeed the impact of a minor injury could well be far more significant for a solo operator with no colleague to call in for occasional assistance.

5.3.2 Site procedure

5.3.2.1 Preliminaries

The subjects were sent the Information Sheet and Informed Consent form (Appendix 1) in advance. Extra copies were taken to the site in cases where these had been lost or misplaced. In two cases inadequate literacy to understand the documents sufficiently was suspected and the sheets were read in full. Once read through, any points arising were discussed. Informed consent form was obtained for 100% of the investigations; the forms usually being signed at the end of the time on site, by which time trust had been established and the subject knew the nature and extent of the data being taken away for analysis.

5.3.2.2 Location of investigations

The data collection was carried out on the farms where the riders had been working, except in four cases where the subjects had been specialists or contractors (e.g. weed and pest control) at the time. Investigations were completed on site, and where conditions permitted, at the exact location where the LCE took place. Damage to machines was inspected to check consistency with the verbal account from the subject, or if repaired, dockets itemising work were viewed.

5.3.2.3 Use of models

Models of quadbikes, trailed implements and riders were used with the intention of assisting interviewees to reconstruct the event and to explain visually to the researcher the detailed mechanics of the LCE. Models are used by off-road training specialists in New Zealand to explain various riding techniques, risks and safety practices when conducting quadbike training sessions (demonstrated to the researchers during the context studies reported in Chapter Four). The literature on the use of models in this way was found to be very limited and restricted to the field of forensics. There were no references found in the occupational health and safety literature. However, it was decided to adopt it as an experimental method for this study due to the interest shown, and willingness to use the models, by the participants at the quadbike skills training sessions.

Two scales of model were used. A smaller 1:32 scale set of quadbike with two trailed units (Figure 5.4) was commonly used by the subjects for recreating event sequences.

Figure 5.4 Scale (1:32) model of Honda utility quadbike with trailer and trailed spreader hopper

A larger 1:24 scale model (Figure 5.5) with a highly articulated figure was used predominantly for analysing contact events, entrapment configurations and post-contact events. The figure had swivel movement at the neck, wrist and waist; and pin joint single axis movement at shoulder, elbow, hip and ankle. Both sets of models were generally required by the subjects.

Figure 5.5 Scale (1:24) model of Yamaha quadbike with articulated rider

Figure 5.6 shows the 1:24 models in use during a reconstruction by an Auckland farmer. He lost control of the quadbike while descending a slope – which he has used cardboard to simulate. This results in the machine being stuck and held upright on its side amongst soft vegetation and boggy ground at the bottom. The fabric represents the soft matter. The legs are awkwardly trapped, one pinned beneath the machine and the other wedged and injured behind the wheel arch. The soft overgrown conditions holding the quadbike in position, entrapment, and reduced limb power makes it difficult for him to apply enough force to roll the machine off. Being at the base of the slope in undergrowth he is not conspicuous and so in danger of lying unseen for longer.

Figure 5.6 Example of an LCE reconstruction using models and props, on a farm in the Auckland region

5.3.2.4 Use of photography and sketches

Photographs and sketches were used to analyse and record event details and sequences. The sketches could be later directly overlaid onto prints as records. Figure 5.7 and Figure 5.8 show two event sequence sketches overlaid onto actual photos of the terrain. This tool was of particular use in cases where the weather was too bad to stay on the LCE site for a long enough period of time. Digital photography alongside sketches also permitted input by other family members and colleagues who had not accompanied the researcher and subject out to the site, back at the farm afterwards, if appropriate.

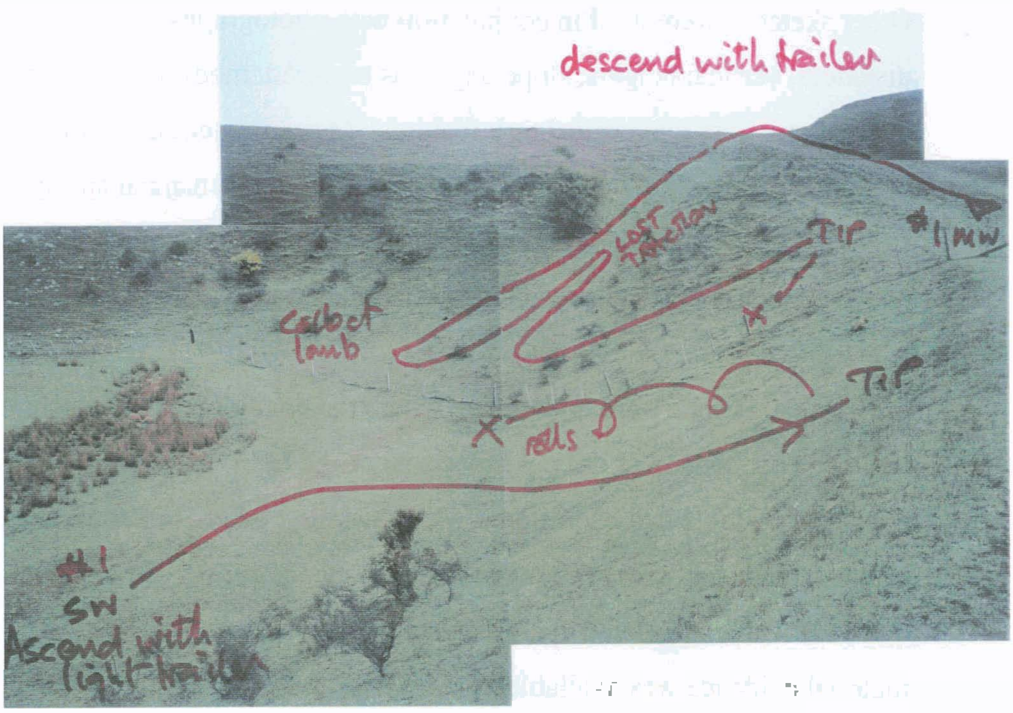

Figure 5.7 South Island LCE site with analysis overlay sketch

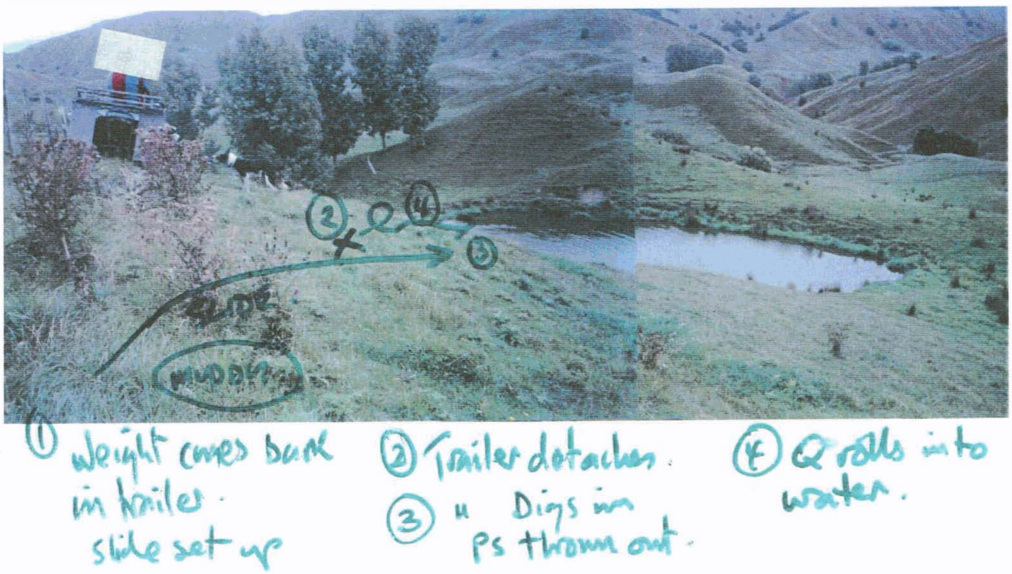

Figure 5.8 North Island LCE site with analysis overlay sketch

The photographs were essential for subsequent analysis with the subjects of terrain. ground cover vegetation, exposure – remoteness, surface damage by animals, erosion, track suitability, route alternatives, Other sketches were used in conjunction with photographs and samples to record distances, vertical heights, slope angles as required, modifications to the quadbike, loading practices and critical task features. Measuring equipment taken to site comprised: 30m cloth tape, 8m steel tape, 1-100kg mechanical spring scale with cargo net and two field inclinometers. A tyre depth gauge and 1-20psi pressure gauge were also carried for checking quadbike, trailer and other implement wheels.

Mechanical checks were undertaken where the condition of the machine had remained unchanged in critical aspects since the LCE, for example, where the damaged machine had been stored while awaiting parts. In a few cases, photographs of the damage had also been taken for insurance purposes. In either case, this evidence was triangulated against the other data sources for the LCE. Where no such material evidence was available, the machine used in the LCE was still used as a context dependent memory cue. The researcher requested that the actual machine was brought to the LCE location wherever possible for the rider to sit on and use as a prop to demonstrate the event sequence and details.

5.3.2.5 Use of video

Where the movements were complex the explanations were video and audio recorded for later interpretation – assuming informed consent had been received.

5.3.2.6 Triangulation of data

Objective corroboration in the form of material evidence was requested wherever feasible. For example, accounts of rollovers were compared to actual machine damage patterns and injuries as recorded in workshop invoices and medical papers held by the subjects. Machine usage estimates were also checked against the odometer and hobbs (engine hours) clocks on the quadbike. Verification of time of LCE and time elapsed between an LCE and getting back to base was sought from others on the farm at the time, as well as diary entries for time markers and cues such as vets visits or stock collections.

It was found to be important to explain to subjects that this was not because the researcher did not believe them to be telling the truth to the best of their ability, but that for no fault of their own their version may have departed from fact in ways that could still be corrected by triangulation of data.

5.3.3 Investigation method development

5.3.3.1 Event charting

Graphic representations of the sequence of events and their causal factors have been used for decades in industry, but the literature contained no specific field-based methods for investigating off-road vehicle-based injury incidents that could be adopted and serve the purpose in full. As discussed elsewhere in this thesis, the Primary Industries generally have not been well-served by ergonomics research historically, but methods have been refined for other industries.

Many graphic methods have fundamental limitations, for example "are deterministic, causal models developed for technical installations" (Svedung & Rasmussen, 2002), which do not incorporate social and organisational factors. Dekker's (2002: p 97) model from the aviation industry is an example of this, in that the analysis encodes the subjects' accounts of an event into a finite set of Human Factors concepts (eg. Poor Feedback, or, Loss of Mode Awareness) rather than capturing through the use of multi-level charts, the reasons why the wrong decision, or act, made sense to that person at the time – in their own language.

A graphic event investigation method capturing a description of the incident is the Sequence of Events and Causal Factor chart (Haslam & Bentley, 1999), shown in Figure 5.9.

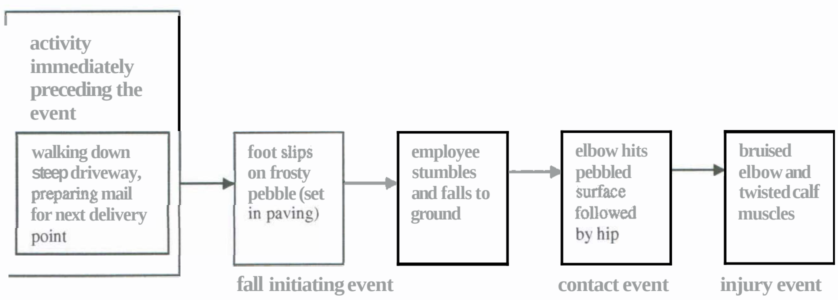

Figure 5.9 Example sequence of events chart (redrawn from Haslam and Bentley, 1999)

In addition to recording the sequence of events, the method plots identified contributing factors at their point of interaction in the sequence, including information processing failures. It also notes the possible organisational influences that may underlying problems to address. The full chart is shown in Figure 5.10

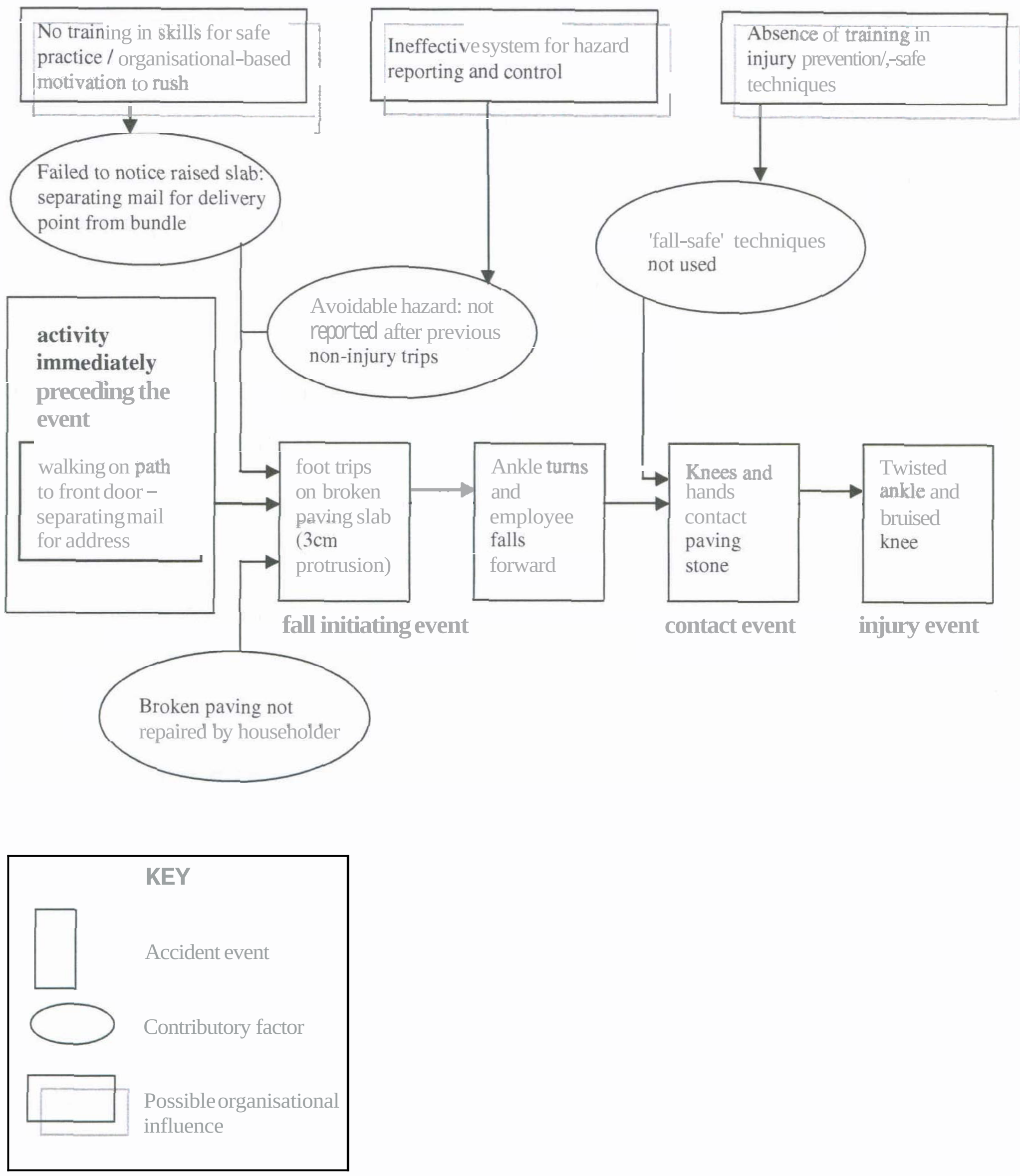

Figure 5.10 Example events and causal factors chart (adapted from Haslam and Bentley, 1999)

The Haslam and Bentley chart shown in Figure 5.10 was modified for the quadbike application by extending the sequence of events to also cover the post-injury phase. Lack of prompt medical help is a critical feature in many remote area LCE.

5.3.3.2 Event charting and analysis design

> **Understanding why so many people die on the roadways each year depends on more than (just) the interactions between driver, their vehicle and the roadway environment.** (Lee, 2006)

Svedung & Rasmussen argue that for a socio-technical context, a cross-disciplinary approach is needed, reflected in a vertically oriented, predictive model for the particular work system. Their vertically oriented model reflects the presence of risk managers operating individually and interactively at all levels in the system. This is appropriate for quadbike use in farming where risk management is influenced at many levels including: the individual rider, the supplier, the farm owner, educators/trainers, the media, farming lobby groups, the Department of Labour, Industry Regulators and Government Ministers.

The event investigation method adopted centred on capturing a description of the LCE on a Sequence of Events and Causal Factor chart, based on work by Haslam and Bentley (1999). The Haslam and Bentley chart shown in Figure 5.10 was used for work on slips, trips and falls with the British Royal Mail delivery service. It was modified (Figure 5.11) for the quadbike application by extending the sequence of events to cover the post-injury phase as well.

The rationale for this modification to the Haslam and Bentley chart is that quadbike LCE in New Zealand generally occur off road and often in remote locations where post-event factors can have a very marked impact on final outcomes. The rider is in most cases alone at the time without anyone to provide immediate assistance, and with the trend towards reduced staffing levels on farms it may well take longer before they are missed and a search initiated. Due to remoteness and hilliness of terrain, mobile telephone or radio communications may also be unavailable or unaffordable for all or parts of the property. There can, therefore, be considerable delays in getting help to the event site if the person is trapped or otherwise incapable of getting back without help. These delays can obviously make the outcomes of injury events considerably worse, and/or the rehabilitation period longer.

The most critical factor contributing to survival *after* a crash is the time it takes to get the driver to the emergency room.
(Redelmeier & Tibshirani, 1997)

Critical post-injury events can also include injuries being aggravated by the worker endeavouring to continue to work, by attempts to make their way back to base unaided, or by failing to make their own way back in time.

Of the 15 ATV–related fatalities on New Zealand farms in the two years from June 2000, OSH concluded that: one was from a head injury, one from impact with a train, four loosely defined as 'from rollovers' and eight were from being crushed / pinned [including resulting in drowning] by the quadbike. Head injuries are more likely to result from being thrown forward at some speed rather than from being crushed in slower rollovers, and so in up to 80% of these fatalities post-event entrapment exacerbating crushing/pinning damage could have been important elements. The road traffic literature recently reviewed (Lee, 2006: 207) indicates that 'the most critical factor contributing to surviving after a crash is the time it takes to get to the emergency room.' There is no reason to assume that off-road crash victims are any less sensitive to delay.

The Haslam and Bentley chart was therefore extended (Figure 5.11) to cover this critical period between the injury event taking place and medical stabilisation.

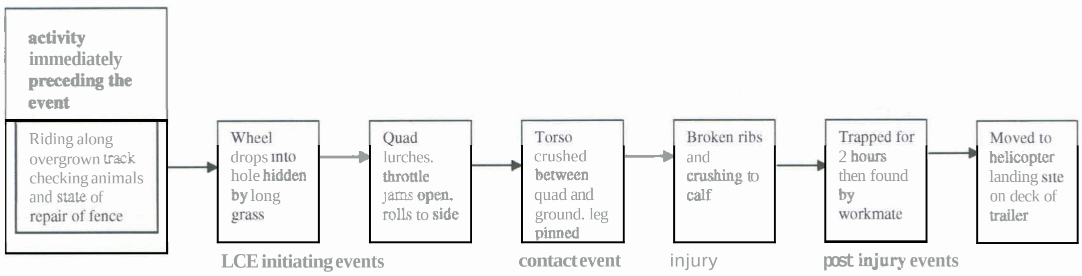

Figure 5.11 Modified chart (sequence boxes only) with example data showing post-injury events

A second modification was the formal inclusion of the Why? Why? Why? prompts on the chart template used on site. This technique to press the line of enquiry to several stages removed from the immediate causal factor was identified in the air accident investigation literature (Zotov, 1999, p 296) as a useful field aid, and was trialed during pilot studies on three sites in the Bay of Plenty. Zotov suggests that the WHY question should be posed at least five times for each line of enquiry in aviation, but in the arguably shallower systems of owner-operator farms, three repetitions proved consistently workable in revealing latent organisational contributory factors. The device was found helpful as most riders in the pilot volunteered underlying organisational reasons for day to day things going wrong when the issues were within their personal control, but not when beyond it. Matters deemed unchangeable were not analysed in the same depth. Being interested in the recording process though, and what was being recorded, the subjects generally watched closely as the event chart was being drawn, and therefore noticed the gaps which they then discussed. In helping to complete the form, critical thinking about topics normally accepted as 'givens' was prompted to the necessary consistent depth for underlying factors to be plotted.

The final version of the modified chart used for this research is shown in Figure **5.12**

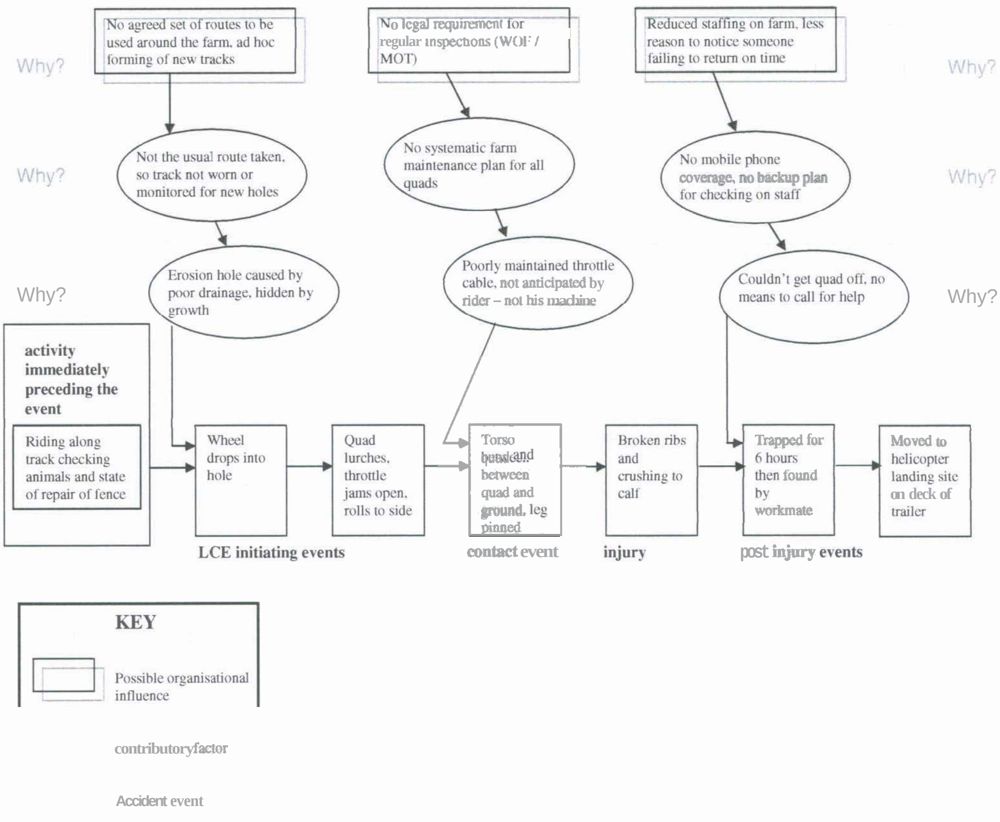

Figure **5.12** Event and Causal Factors chart for **quadbike** LCE (example) final version

Examples of completed event charts with accompanying context study notes for three individual mustering, spraying and fencing-related LCE are included in Appendix III.

The investigation method provided a workably systematic framework for discussing, analysing and recording events and the factors behind these. The participative re-examination of the events allowed pre-existing causal schema (Lehane & Stubbs, 2006) to be reviewed and confirmation bias reduced. The structured approach also drew out important information that was so obvious to the respondent that they may well have omitted to mention it.

'...the experience of all highly developed sciences shows that the clear, explicit formulation of 'the obvious' and its incorporation in the systematic treatment of a subject is both necessary and very convenient. We are all liable to neglect, or overlook, or forget such things, especially when we wish to, and above all when we so wish unconsciously'.
(L.J. Henderson, from his Sociology 23 Lectures 1941. Published in: Barber, 1970. p62)

5.3.4 Intervention development

5.3.4.1 Intervention development approach

As explained in Chapter One, the development of pragmatic potential interventions was not only desirable from the point of view of the research funders, but was also found to be essential to the method in that it gave meaning to the exercise in the eyes of the participants – without which their cooperation could not have been gained. Likewise, the support of the farming press and local radio was integral to the method, and this could not have won without a cohesive ('what's the problem, and more importantly, what can we do about it') approach that made sense to both the journalists and their audiences. Dialogue was initiated with many users during the main industry consultation phase of the context study, continuing throughout the research period – and beyond, as illustrated in Figure 5.13.

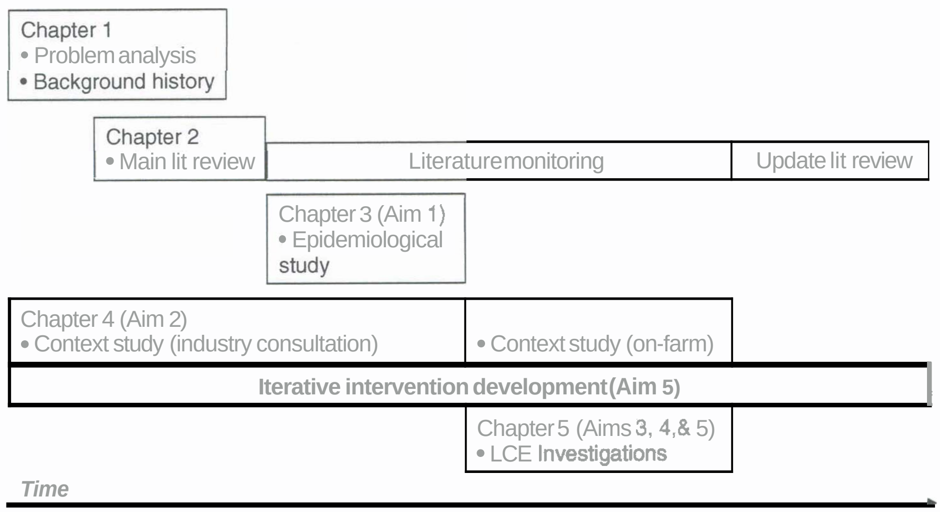

Figure 5.13 Sequential progression of studies

Table 5.4 summarises the main areas of intervention interest of the primary groups involved in the iterative development of the intervention matrix described later. Due to the relatively high national profile of this research and therefore the potential weight of influence that it was thought the published final report may carry, it was not difficult to establish and maintain dialogue with the various interested parties on the potential intervention recommendations that might emerge.

Table 5.4 Sources and main areas of intervention interest

System Level and Sources	Main areas of intervention interest
Government agencies and Regulatory bodies • ACC • OSH • Statistics New Zealand	• Design specification control through import regulation • National level surveillance • Licensing and regulation
Non-Governmental Organisations • AGITO • Federated Farmers • New Zealand Council of Trade Unions (NZCTU) • SafeKids • Overseas counterparts • FarmSafe • New Zealand Qualification Authority	• Reporting and surveillance • Community-wide initiatives • Employment terms and conditions • Usability in design for the youths and elderly • Training needs and successes • Regulation of use through law
Social environment • ACC and OSH local staff • Family members • Farm Discussion Groups • FarmSafe training session attendees • Local Trade Union organisers • Media: journalists, editors, producers	• Change management in rural communities, implementation approaches • Work organisation • Stress, interpersonal and psycho-social • Fatigue • Induction training and supervision
Organisation • Farm owners / managers • Farm Discussion Groups	• Cost-benefit based educational resources • Machine enhancements • Physical environment management
Corporate • Importers / dealers • Manufacturers of accessories and appliances • Localmechanics • Personal Protective Equipment (PPE) designers and retailers	• New products to sell as additions to the existing systems • Skills and maintenance training • Competency screening • Warnings
Riders • 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 • Farm visitors and other infrequent users	• New products • Modifications • New vehicle concepts • Intuitive and counter-intuitive features • Communications for riders to base • Better suited storage/stowage systems

The following is an example of a typical contribution from a farmer in response to articles asking for comment on potential interventions in the later stages of the consultation.

> *Dear **Dave**,*
>
> ***Having** read the articles in Fanners Weekly.. I have been fortunate to survive **unscathed five** ATV rollovers caused by hidden holes in March pasture.*
>
> *The first reaction to an impending **rollover** is to put your foot down and push, then as the weight overpowers your strength, I have schooled **myself and** others to slip (and) roll, **mov(ing) rearwards** and **downhill.** My generation of 'no safety cabs on tractors' were all told anyone trying to escape uphill dies.*
>
> *My concern is the new practice of a rail and filled in area wide of the foot area, shutting off the opportunity to plant the foot, diminishing the ability to escape. This could be tested by controlled rollovers. At 76 I now elect to **carry** in a knapsack **sprayer** as I recognise my reduced ability.*

A significant motivator for some subjects was the passionate desire to see matters improve, and many therefore came forward in order to get their ideas listened to by someone who they perceived to be in a position to influence change. The tone of the interviews on the farms was therefore a positive one with similarities to underlying principles of Appreciative Inquiry methods (Cooperrider & Whitney, 2000) such as the Principle of Simultaneity whereby inquiry and change are simultaneous. The focus was on building on strengths of the current systems 'what works' rather than solely 'criticism, negation and spiralling diagnosis'.

5.3.4.2 Stepped iteration design

Theoretically, fact-finding in professional fields is completed prior to any design conclusions being drawn (Moore, 1996). In practice this is rarely if ever the case, and certainly for these series of studies, delaying the start of this aspect of the research was neither desirable (for reasons as explained above) nor affordable. The enthusiasm of the industry to see positive changes needed to be harnessed through use of a method that allowed ideas to be captured at any stage for later analysis and testing. There were also not the resources to make additional visits to all the farms subsequently to develop interventions, nor could multiple visits to the subjects have been attempted without excessive erosion of goodwill. In addition, there were certain unequivocal and complex intervention areas, such as improving the stability of quadbikes during mustering, that had emerged from the earliest stages of the studies, and on which protracted and careful consultation was needed to develop workable countermeasures that did not have unwanted and 'unexpected consequences' (Lee, 2006).

5.3.4.3 Intervention matrix

The potential interventions developed iteratively over the course of the studies were captured on a framework shown in Table 5.5 This uses the well-known Pre-Crash, Crash, Post-Crash matrix by Haddon (1999) first published in 1968 and still influential in injury prevention (Runyan, 2006). Added to Haddon's original human, vehicle and environment categories are the more distal Government and Regulatory categories used by Rasmussen (1997) to depict risk factor interactions for driving safety "in a dynamic society."

For the purposes of this quadbike LCE study the categories of organisation and social environment have also been added reflecting likelihood of latent failures (Reason, 1990; Wagenaar, 1998;) to emerge from these levels in a population dominated by family-run businesses. The final addition is that of Cargo, from Haddon (1972). The farm quadbike carries both live and dead load, which may generate or moderate risk factors. The final version has a clear vertical orientation as suggested by Svedung & Rasmussen (2002) and seen in graphical methods of socio-technical system event capture and analysis such as AcciMap.

Table 5.5 Intervention matrix

Level			
Government			
Regulatory environment			
Social environment			
Organisation			
Physical environment			
Cargo			
Machine			
Rider			
	Pre-LCE	LCE	Post-LCE
Event sequence →			

5.3.4.4 Iterative refinement

Interventions that had relevance to the situation in hand were discussed at each farm. The matrix was added to and existing intervention ideas refined participatively with these subjects.

At research project reporting points, the matrix contents were also reviewed by the stakeholders group. Complex technical matters such as changes to the design of spray tanks were subject to further consultation over a number of stages with the relevant manufacturers, other users and specific industry bodies such as Standards New Zealand.

During the project, feedback on the more advanced potential interventions was also sought from the wider farming community through the popular farming media.

5.3.4.5 Consultation on farm-specific action plans

The final package of interventions was discussed formally in a facilitated session with a Farm Discussion Group in the Catlins district of Southland in September 2003. It is one of 600 such groups in New Zealand, covering the whole country. The aim was to collect data from the field on how to most effectively use the matrix contents to help formulate customised action plans for individual farms that built upon the strengths of the existing systems and addressed the weaknesses.

13 farmers (representing 40% of all farms in the catchment area for that Discussion Group) took part in the session which comprised discussion on the findings of the studies, and also the interventions matrix. A 13-page information pack was provided to the participants giving a summary of findings and list of the draft interventions. The researcher also provided props (Sinclair, 2005) – quadbike and rider models, articles of quadbike PPE, photographs of vehicle types, etc which proved invaluable for members demonstrating points and also for stimulating detailed discussion relevant to the agenda without Moderator guidance. The researcher prepared the agenda and acted as moderator to balance contributions, but in both cases the sessions were Chaired by the group member hosting the event – as is desirable for

these groups (Haslarn, 2003) as it allowed the researcher to act as scribe. Audio recording was not appropriate in the informal but commercially sensitive atmosphere of these meetings.

Five volunteer farms also subsequently provided draft action plan data on pro-forma sheets prepared for the session and returned these to the researcher. The findings of the session were analysed and conclusions incorporated into both the format of the intervention lists and the recommendations for further research.

5.4 Findings

In this section, individual rider characteristics are firstly discussed, followed by temporal factors, terrain/ground factors, task-related factors, event sequences and risk factors. An interactive, information processing model is proposed for the analysis of quadbike LCE on farms. Finally, findings on potential interventions are outlined.

Serious injury is defined for the purposes of this study as any: head injury, fracture, injury resulting in hospitalisation, or injury resulting in some other loss of function which significantly diminished farm performance. Some 37 of the LCE investigated resulted in injuries were thus classified as serious.

5.4.1 Rider/individual factors

The following findings describe the characteristics of quadbike-related LCE, specifically: employment status, age and sex distribution, isolation, injury types.

5.4.1.1 Employment Status

Table 5.6 presents a comparison of employment status between all riders identified on farms and those reporting a recent LCE. Working farmers are over represented in comparison to family members, and to a lesser degree, employees. Doing less risky tasks or under less pressure may be factors in the low incidence of LCE amongst family members (26% of riders but only 6% of LCE).

Table 5.6 Employment status of quadbike users

Status	All quadbike users on the farms studied		LCE subjects		Serious injury LCE	
Farmers	54	54%	45	70%	27	73%
Family members	31	26%	4	6%		
Employees	29	24%	10	16%	7	19%
Contractors	3	3%	3	5%	3	8%
Other	3	3%	2	3%		
Total	119		64		37	

5.4.1.2 Exposure to risk

Average hours per week on the quad throughout the year in comparison to the busiest weeks during the year, are shown in table 5.7. Nineteen cases were excluded through insufficient verification being available (logbooks, timesheets, etc) to objectively support these estimates.

Those reporting recent LCE are not significantly ($\chi^2 = 0.53$, df=3, $p \leq 0.05$ level) heavier users of quadbikes normally during the year than those not reporting LCE. However, as the Table shows, they are spending on average 60% more time on the quadbikes than the others on their farms at the busiest times. This increase for the LCE subject group is a highly significant increase, in comparison to both their annual average exposure ($\chi^2 = 18.35$, df=4, p S 0.01 level), and also to the Other Riders group ($\chi^2 = 14.3$. df=4, p S 0.01 level) at their busy times.

Table 5.7 Hours of quadbike use per week

Status	Mean hours riding per week - estimates	Mean maximum hours ridden per week at busiest times
LCE subjects (n=53)	10.5 hrs (range 1-40)	20.1 hrs (range 1-50)
All other riders on these farms (n=47)	7.7 hrs (range 1-40)	12.3 hrs (range 1-50)

When expressed as a percentage in graph form (Figure 5.14) the extreme deviation of the LCE subjects at their busy times is evident.

Longer hours of use per week may increase risk simply by the proportional increase in exposure. It is also possible that the nature of the work at these busy times (lambing / calving) and the fatigue associated is significant – increasing the level of risk per hour. Further specific study is required.

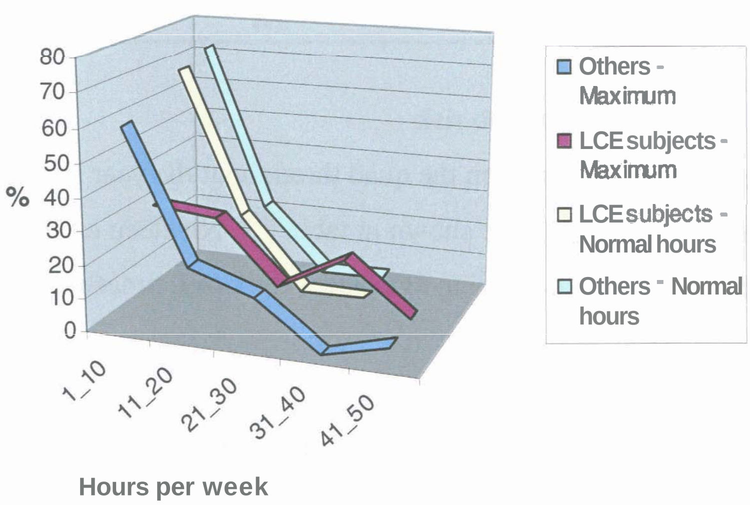

Figure 5.14 Hours of quadbike use (exposure) per week, by percentage

Three contractors were included in the sample. Their exposure hours, verified by documentation and testimony from the farms concerned, were very high, averaging just under 50 a week. Farmers, and to a lesser degree employees, generally have significant variety in their daily duties for much of the year – or at least the opportunity for variety. By contrast, contractors are entering the industry as specialist service providers and may be working intensively on a small range of tasks on many different properties within a given season. The contractors in this study were all heavily engaged in spraying, which, as has been discussed earlier, is a hazardous activity. Contractors add to the risks by using bigger capacity fluid tanks to get the job done faster, and therefore also buy heavier more powerful quads to handle the extra load. In the result of a rollover serious injury is therefore more likely.

5.4.1.3 Gender

The epidemiological data reported in Chapter Three indicated under-representation of adult women in the ACC claims data. This was echoed in the findings for this study. Table 5.8 shows the male/female split of those having serious injuries as a percentage of the total rider population. Females featured in less than one in ten of the LCE (8%) and the serious injury cases (8%) but comprised over a quarter of the quadbike riding population on the case study farms. This is significant ($\chi^2 = 8.92$, df=1, p 50.025 level).

Table 5.8 Gender of rider

	All quadbike users on the farms studied	LCE subjects	Serious injury LCE
Males	71% (n=84)	92% (n=59)	92% (n=34)
Females	29% (n=25)	8% (n=5)	8% (n=3)

5.4.1.4 Age and experience

The **ACC** data indicated a peak of injuries in the 41-50 age group. The findings from the on-site investigations in this study were largely consistent with this. Table 5.9 shows the age, experience and peak workloads of all reported users on the farms in comparison to those **LCE** subjects incurring the serious injuries.

Those getting seriously hurt are older. This group may also be doing more quadbike work at busy times. This fits with a common description given anecdotally by subjects when asked for their impression of the highest risk overall group. Family men, past 40 and with considerable and varied responsibilities on the property; too much to do, too much on their mind and with a body that will not react as fast or withstand heavy contact as it did when they were younger.

At the outset of the study it was suggested within industry that inexperience on specific farms may be the main reason for injury from **LCE.** The findings do not support that however. In less than 10% of investigations was inexperience suggested as a contributing factor, and the experience of riders with quadbikes was not found to be a significant predictor of serious injury.

Table 5.9 Age and experience of all riders and those being seriously injured

	All quadbike users on the farms	Serious injury **LCE**
Mean age of subjects	40.7	46.4
Years of experience on quadbikes	13.5	13.6

5.4.1.5 Injuries by types and body region

In the ACC data reported in Chapter Three, injuries were most frequently located at the knee and lower back. Other high-frequency body part regions were the shoulder and chest, both of which involved a relatively high proportion of fractures or dislocations.

Injury sites to the body in this study are shown in Table 5.10. The pattern for all LCE echoes that of the ACC data with a high incidence of lower limb cases.

Table 5.10 Body region by injury types for all LCE (n=156)

Body region	Strain/sprain % (n)	Cuts and grazing % (n)	Fracture or dislocation % (n)	Total %
Multiple minor injuries	42 (66)	38 (59)	0	80
Lower limb	14 (22)	2 (3)	4 (6)	20
Chest	6 (9)	1 (2)	3 (5)	10
Back	4 (6)	1 (1)	5 (7)	10
Upper limb and shoulder	4 (6)	1 (2)	1 (2)	6
Head/neck	4 (6)	1 (2)	1 (1)	6
Total	74 (115)	44 (69)	14 (21)	132*

* **More than 100% due to cases of multiple injuries**

Table 5.11 shows that in the more severe outcomes, over half of specific injuries relate to the lower limbs or chest.

Table 5.11 Serious LCE injuries by body region (n=37)

Body region	%
Lower limb	33
Chest	27
Back	16
Upper limb and shoulder	16
Head/neck	16
Multiple - unspecified	14
Total	122"

* **More than 100 due to a number of injuries involving two or more specified regions**

These findings have implications for the design of secondary safety systems and personal protective equipment (PPE). The practice of fitting bullbars and other tubular metal structures to the machine in order to protect the quadbike from damage may well be increasing point-load damage to riders in roll-overs. Handlebars and display consoles similarly act to increase potential for rider injury, especially at the chest. Interventions targeted at reducing crushing potential, in these two regions in particular, appear warranted.

5.4.1.6 Isolation

The findings from the context study reported in Chapter Four suggest that increasingly farm-work is being done in isolation due to greater mechanisation, increased labour costs and smaller profits, which together combine to reduce numbers of employed staff. This could impact on quadbike safety as riders may lack assistance with tasks that warrant two people, and may be waiting a lot longer for help if trapped or incapacitated after a LCE. It could be reasonably be expected therefore that a higher proportion of the serious injuries would occur in isolated situations – by comparison to those LCE with less serious injury outcomes. Interestingly, the findings of this study did not support that however, as shown in Table 5.12.

Table 5.12 Working in isolation and severity of injury

	All LCE %	Serious injury LCE %
Working alone	76	73
Not alone	24	27
Total	*100*	*100*

5.4.2 Temporal and seasonal factors

5.4.2.1 Time of day

Figure **5.15** shows temporal peaks in LCE reporting at late morning and mid afternoon. The 50 cases where the specific hour of the event could not be recalled or calculated confidently through other lines of evidence have been omitted from this analysis.

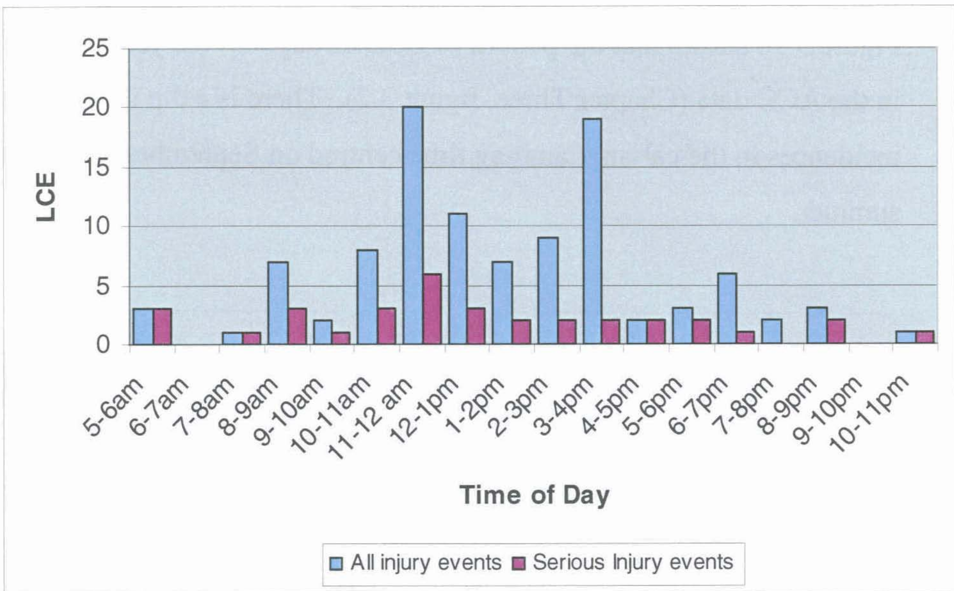

Figure 5.15 LCE by severity and time of day

The interpretation of these findings drew on the understanding of the systems gained during the context study. The peaks are at the times when New Zealand farmers are predominantly getting ready to go, or are going, home for lunch; and similarly in the afternoon when they may be going back to base for the afternoon break, or for the second milking. Lunchtime centres on the period 12.30 - 1pm traditionally on New Zealand farms, and this is adhered to with remarkable consistency across the country despite changes in household and labour structure. It is possible that recall was higher where the event was linked to another temporal marker such as lunch.

Circadian influences and patterns of eating and drinking may be further factors as there are similarities to findings from previous studies in New Zealand primary industries. A spike in reported logging injury incidence in the hour before the main break of the day has been noted recently (Bentley & Parker, 2001; Parker et al., 2002). Contributing factors in this case were suspected to be fatigue (Kirk & Paterson, 1996), and dehydration (Bates et al., 2001).

5.4.2.2 Time of year

Figure 5.16 shows that the pattern of LCE throughout the year is similar to that found in the ACC data (Chapter Three, figure 3.2). There is a dip in winter and peaks of incidences in the calving/lambing time centred on September and during the high summer.

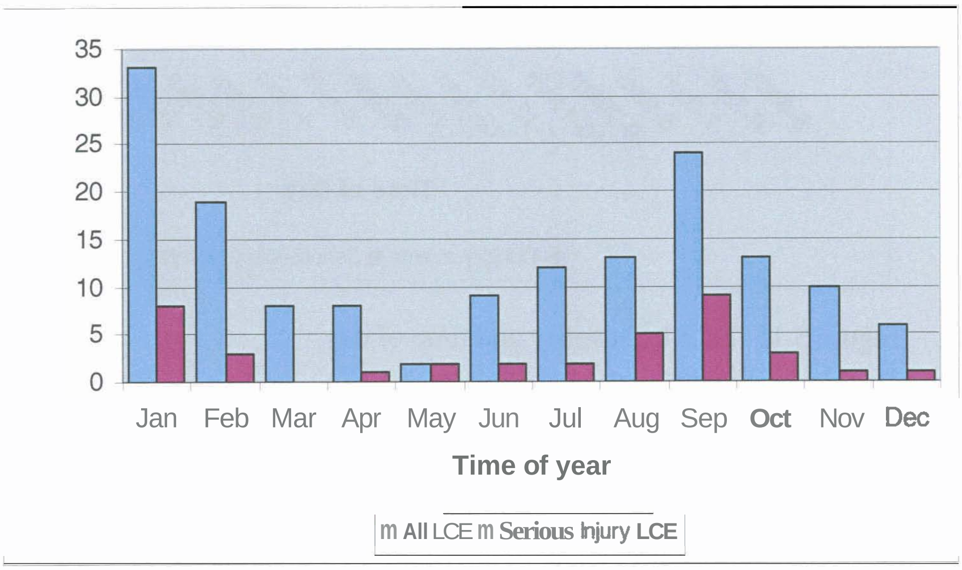

Figure 5.16 Loss of Control Events by severity and time of year

Farming is obviously a very seasonal industry, with activity intensification occurring during crop harvesting for horticulturalists, and calving / lambing on livestock fattening and dairy farms. September was the peak month for calving and lambing at the time of the study, although commercial incentives have now brought this forward to August and in some places July. Horticultural harvesting periods vary a lot depending on the crop (ranging from late spring to autumn), and quadbikes are rarely used in horticulture in comparison to stock-based operations. Only 3% of the LCE in the study are from the horticultural sector. Seasonal effects from this sector on quadbike LCE in this study can therefore be discounted.

The September spike in incidence for all LCE, and the LCE with serious injury outcomes by month of incidence, is in line with these seasonal activity patterns, but the pronounced January spike is not. The context study revealed a number of factors that may contribute to this intriguing finding.

Quadbikes work best in soft conditions where the contact area between tyre and ground is high. They will loose traction more easily on hard ground, especially if the surface has been made slick by a shower or lush growth. The dry weather also turns soft malleable ridges into hard ruts that do not conform under tyre pressure. In 15 of the 33 LCE cases these hard, rutted, or slick conditions were identified as a major factor in the loss of traction leading to the LCE.

January is the also main holiday month for families in New Zealand with schools, universities and many workplaces closed for all or much of it. More family visitors are present on farms as well as fill-in staff such as students covering for those on holiday. Inexperience or unfamiliarity with the machine was found to be a factor in six of the 33 cases that month.

In four cases, the activity immediately preceding the January LCE was weed control. This inherently hazardous activity can only be carried out only in dry settled conditions, in order to minimise spray drift and maximise plant uptake. January and February are the most suitable months of the year for this.

5.4.3 Terrain/ground factors

5.4.3.1 Ground conditions

Over half of all LCE take place on hard ground as shown in Figure 5.16. Adding together all on hard ground – both those with dry and wet surfaces – it can be seen that only about a third take place in the muddy wet slippery conditions that would prove the more problematic for heavier vehicles such as farm utility (pick-up) trucks.

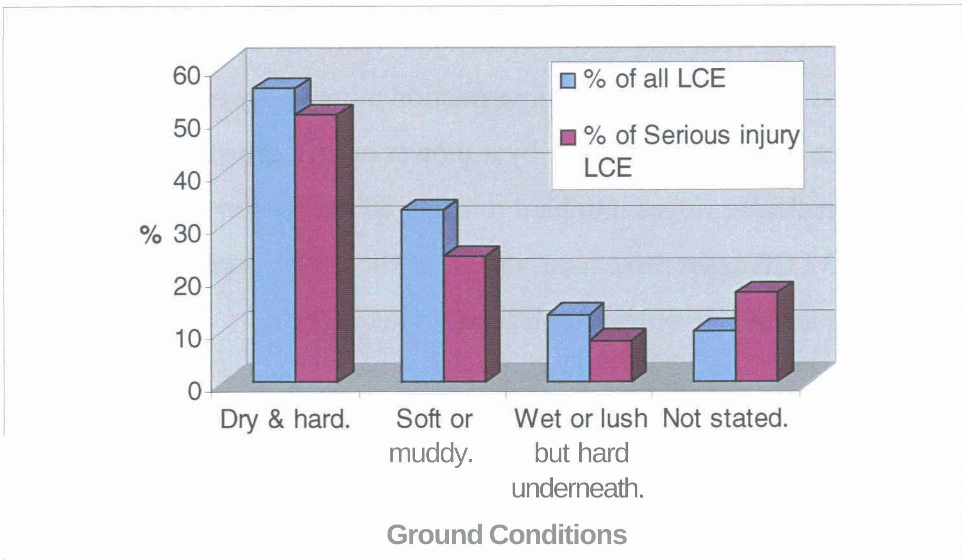

Figure 5.16 All LCE and those resulting in serious injuries by ground conditions

5.4.3.2 Terrain

Although less quadbike LCE occur on the flatter land overall – in line with popular expectation, a much higher proportion of those that do occur here result in serious injury, as shown in Figure 5.17. Thus 55% of LCE on flat-undulating-rolling terrain resulted in serious injury, as opposed to only 18-19% of those LCE taking place on steeper ground.

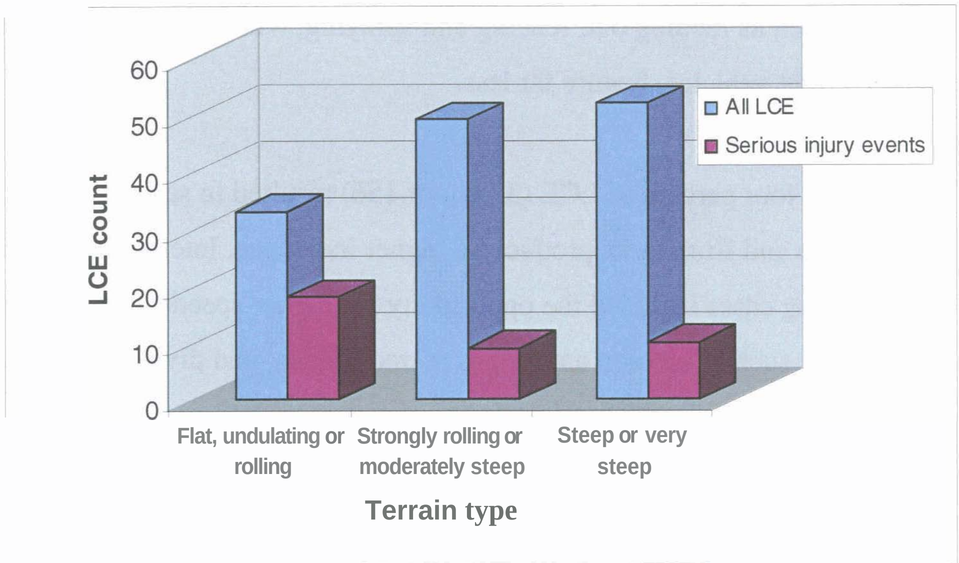

Figure 5.17 All LCE and those resulting in serious injuries by terrain type

Factors relevant to this certainly include a greater likelihood of entrapment (see 5.3.6.4) for riders not on steep slopes, as without gravity to assist them the machine is far harder to roll off injured body parts. Further study is required to investigate possible relationships between: terrain type and task, steepness of terrain and speed at the time of LCE, and also potentially reduced perceptions of risk for riders when operating on less dangerous-looking ground.

In four cases the absence of an effective park brake to use on the slope was specifically cited as the primary factor, either through its' failing to hold the machine, or the brake not being applied at all as it was known to be unreliable.

5.4.4 Task-related factors

5.4.4.1 Activity immediately preceding the incident

Table 5.13 shows the task being undertaken immediately preceding the LCE. Stockwork-related tasks are the most common. The second largest category is miscellaneous, which while uninformative in a table, reflects the very wide diversity of task applications where LCE involving quadbikes on farms take place. Other tasks such as feeding out, fencing and spraying, which involve very heavy loads for such light vehicles, feature far less.

Twenty four percent of LCE (37 out of 156) resulted in serious injury on average, but going to and from tasks produced a higher incidence. Interacting factors in these transiting cases included the opportunity for higher speeds, unpredicted surface changes such as erosion and ridges at track edges, and divided attention during the journey.

Table 5.13 Activity immediately preceding the incident

Activity	Total		Proportion of each activity resulting in serious injury
	%	(n)	%
Stockwork (mustering, catching, checking)	37	(58)	22%
Miscellaneous (includes: hunting, use by visitors, testing new quadbikes)	22	(33)	18%
Going to or from stockwork	8	(13)	54%
Spraying or going to or from spraying	6	(10)	20%
Inspection tasks	6	(10)	10%
Fencework [moving, repairing] or going to or from	6	(10)	10%
Going to or from inspection	5	(6)	33%
Contractor work (spraying, pest control, soil testing)	3	(5)	60%
Spreading, rush cutting, rolling, harrowing, firewood hauling	3	(5)	20%
Going to or from feeding out	3	(4)	25%
Feeding out	1	(2)	0%
Total	100%	(156)	

When partially collapsed to allow direct comparison with the context study findings on primary use of the quadbikes, it can be seen (Table 5.14) that no specific task group is over-represented in the LCE – assuming primacy is a reasonable indicator of exposure time. It suggests that despite some tasks such as spraying having clear additional risk factors associated, primacylexposure time to the task may be the most significant variable for overall LCE incidence by task.

Table 5.14 Activity preceding LCE, in comparison to primary use of the quadbikes

Activity	LCE study %	Context study %
Stockwork (mustering, catching, checking), going to or from stockwork	45	53
Miscellaneous use: inspection, hunting, use by visitors, testing new quadbikes.	33	27
Spraying or going to or from spraying	6	6
Fencework (moving, repairing) or going to or from fencing	6	5
Minor jobs: pest control, soil testing, spreading, rush cutting, rolling, harrowing, firewood hauling	6	5
Feeding out l going to or from feeding out	4	4
Total	100	100

It was widely suggested, or implied, during the context study that quadbike LCE were only a problem on hills. Analysis was therefore conducted on the attitude of the machines at the time of the LCE. For each task type, Table 5.15 indicates whether the quadbike was going up, down, traversing sideways across the slope or moving along on a level.

The table shows that 39% of the stockwork-related LCE take place on relatively flat ground rather than during the ascending, descending or traversing of steeper slopes – as might be expected. When cornering hard in amongst stock, ruts a few inches deep are enough to destabilise the machine if the rider's attention is elsewhere and they have not anticipated it. Greater speed and divided attention are also commonly at play in this scenario set – as previously discussed in 5.3.3.2. This, combined with the elevated risk of serious injury if trapped under the quadbike, makes operation amongst animals on benign-looking country especially hazardous.

As might be expected, descent appears more problematic for riders using quads for fencing due largely to the very heavy loads of materials pulled in trailers. Traversing is identified more often for spraying where un-baffled tanks allow de-stabilising fluid surges to the sides.

Table 5.15 Attitude of quadbike travel at time of LCE – by task

Activity	Attitude of travel				
	Level (n=60) %	Ascent (n=34) %	Traverse (n=24) %	Descent (n=38) %	***Total*** %
Stockwork (n=71)	39	23	14	24	*100*
Miscellaneous (n=33)	59	24	3	14	*100*
Spraying (n=10)	30	10	40	20	*100*
Inspection tasks (n=16)	4	31	31	31	*100*
Fencework (n=10)	10	20	10	60	*100*
Contractor work (n=5)	60	40	0	0	*100*
Spreading, rush cutting, rolling, harrowing, firewood hauling (n=5)	60	0	20	20	*100*
Going to or from feeding out (n=6)	33.3	0	33.3	33.3	*100*

5.4.4.2 Ancillary implements attached during the LCE

In 28% (n=44) of the total 156 LCE cases there was a trailer or other towed implement attached to the quadbike at the time. By contrast, only 0.6% of the ACC cases of LCE reported in the epidemiological study in Chapter Three were recorded as involving trailed implements. This will be partly due to the restrictions on ACC narrative text entry which precludes much of the detail. There are also no systematic prompts for ancillary equipment on the claims form.

Table 5.16 Shows that serious injury resulted in 18% (n=8) of the LCE where an implement was involved, which while less than the average incidence of serious LCE, is not statistically significant (at 0.05). Therefore, while trailers certainly increase the potential risk of LCE in certain circumstances such as descent, they have probably not increased or decreased the incidence of serious injury LCE in this study.

Table 5.16 Implements in use during an LCE - by task

Activity	LCE with implement n	Serious LCE with implement attached % (n)
Stockwork	16	25% (4)
Spraying	10	20% (2)
Fencework	6	0
Spreading, rush cutting, rolling, harrowing, firewood hauling	5	20% (1)
Miscellaneous	2	0
Inspection tasks	1	0
Going to or from feeding out	3	33% (1)
Total	44	18% (8)

Eighty seven percent of the farms visited in the context study reported in Chapter Four used a light trailer behind their quadbike(s). A trailer was also the most common implement (n=33) drawn behind a quadbike in the 44 LCE shown above.

The most common scenarios involving these light trailers are shown in Figure 5.18. Over half occurred while climbing, descending or traversing hills where the extra load and altered dynamics resulted in critical loss of traction, and recovery was impaired by the jacknifing of the trailer.

The riders reported that the inability to reverse straight with a trailer on reduces their options once they find themselves getting into difficulty on the hills. The weight on the towbar, and absence of independent trailer braking, can also make it virtually impossible to detach when on a steeply angled slope. With trailer attached they are less likely to be able to get off and drag the nose of the machine around to face downhill – a common technique with lighter machines caught side-on on steep sidlings.

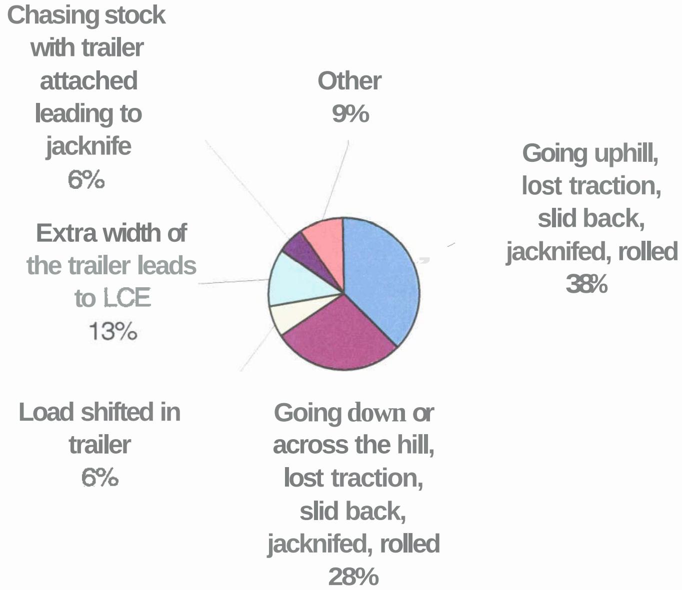

Figure 5.18 LCE scenarios involving trailers (n=33)

5.4.4.3 Injury agency

In 30 cases the injured party couldn't positively identify injury agencies due to the speed of the incident and the disorientation experienced at the time, and there was no means of deducing this from other data sources. The specific part of the quadbike most commonly identified positively as contacting the body was the handlebars (n=13). Figure 5.19 shows the most common injury agencies reported.

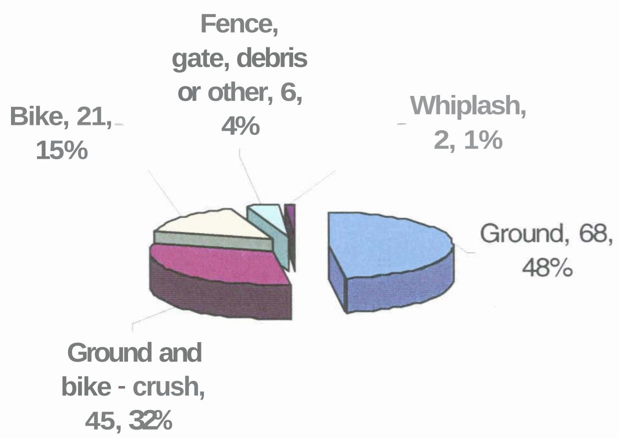

Figure 5.19 Most common injury agencies (n=122)

Of note is that the type of incident common on North American wooded trails where the rider is thrown into objects - rocks, trees etc (45%) (Legare, 2002), is far less common in this study (4%).

5.4.5 **Events**

In this section, the basic features of the sequences of all LCE events are analysed.

5.4.5.1 Event sequences

In 96% of the LCE the machine was being ridden at the time. In four of the remaining six cases investigated, the machine moved after the rider had got off, (for example through failure of the parking park when on a hill) causing the rider to chase and attempt to regain control. In the final two cases, the user had dismounted leaving the engine still running and was walking the machine up or across a steep hillside blipping the throttle. This is a recognised technique as working the throttle while walking on the uphill side makes tipping less likely and gives useful leverage through the handlebars onto the uphill tyres. While generally safer than actually being astride it on such marginal terrain, riders can get injured by being dragged if clothing snags on the machine, and through legs being struck by the machine.

Figure 5.20 shows a taxonomy of LCE sequences for those 96% where the machine was being ridden immediately prior to the incident, and then rolled. This compares directly to the taxonomy Figure 3.4 in Chapter 3 but differs in that a Post Event column has been added, indicating for example whether or not help was close at hand. Of particular note here is that the quadbikes were reported as much more likely to overbalance (69%) than simply slide on all four wheels (7%)as control is lost.

Of the rolls, one in six (n=15) resulted in entrapment. Therefore, in 43% (n=56) of the 130 LCE in the study where the rider clearly reported specific injuries, and an even higher percentage of the serious injury LCE, involved the rider being struck by, or crushed against the ground, by the machine.

The rider also clearly needs to be self reliant and capable of raising the alarm in cases where they are incapacitated by their injuries. In only around a quarter to one third of cases was help on hand to promptly assist the injured person after a rollover.

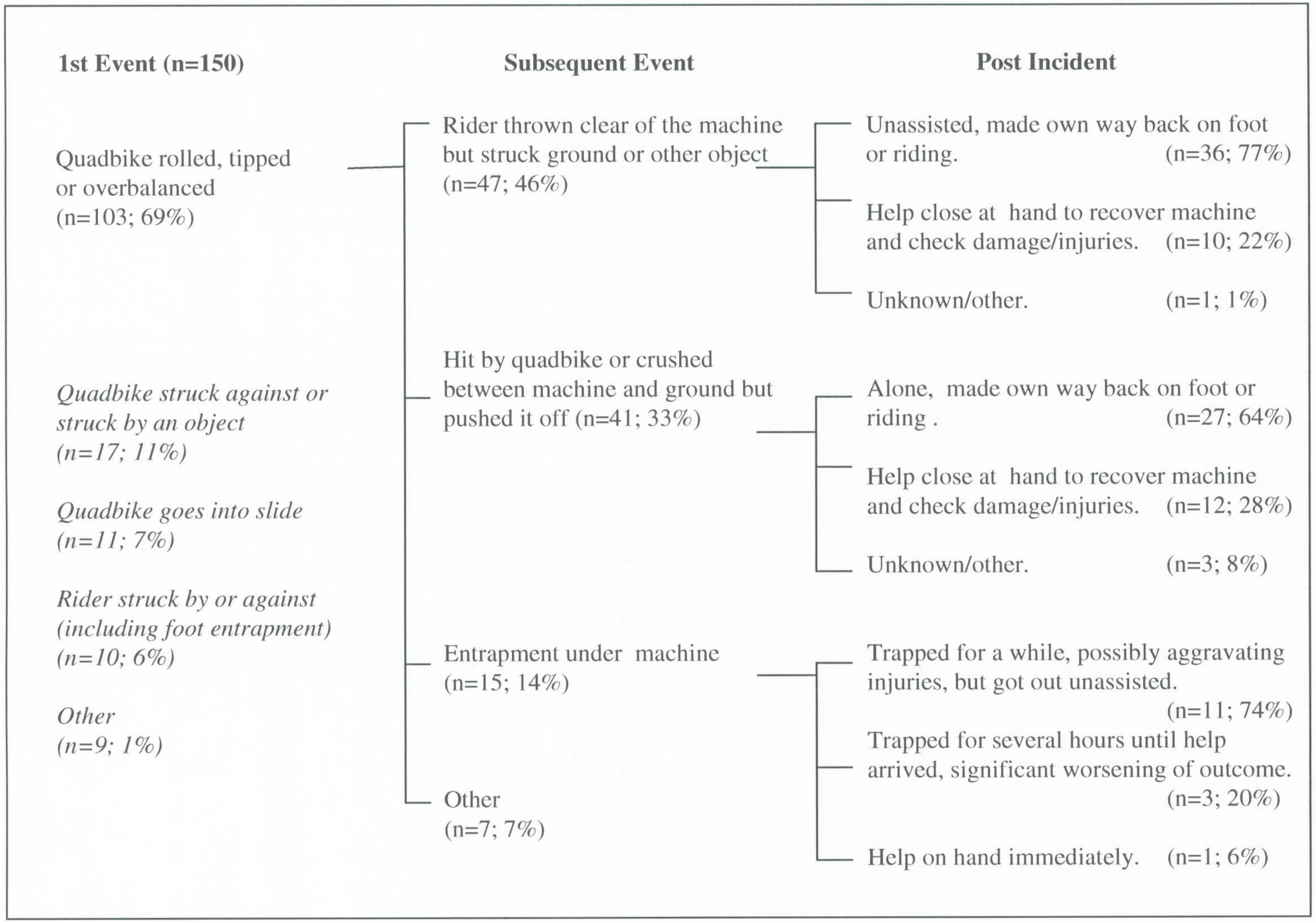

Figure 5.20 Taxonomy of all events where machine was being ridden at the time of the LCE

5.4.6 Risk factors

In this section the risk factors are analysed by major task groupings.

5.4.6.1 Risk factors in LCE involving animals

A large proportion – just under half of all the LCE investigated - involved working with animals in some way. Figure 5.21 shows a taxonomy of LCE involving animals - based on the event charts. The number of total cases is greater than the 58 listed under Stockwork in Table 5.13 (Activities Immediately Preceding the Event). This is due to animals being influential in a number of the events coded under different Activities. For example, in one such case a quadbike rider out mowing grass on a road verge briefly ceased cutting to give chase to a cow that had got out through the fence. The machine hit a concealed branch in the un-mown grass causing a LCE.

The taxonomy presentation uses a graphic format to show the cross-tabulated combinations. This is similar to a method used by Burgess-Limerick (2006). The coding categories were not pre-structured but evolved during the analysis, described by Burgess-Limerick as similar in approach to that of the constant comparative coding method of Glaser & Strauss (1967).

It shows the sub-task and the principle ways in which the animals influenced the LCE; for example, by digging up the riding surface or inducing fatigue through the long work hours required at calving and lambing times.

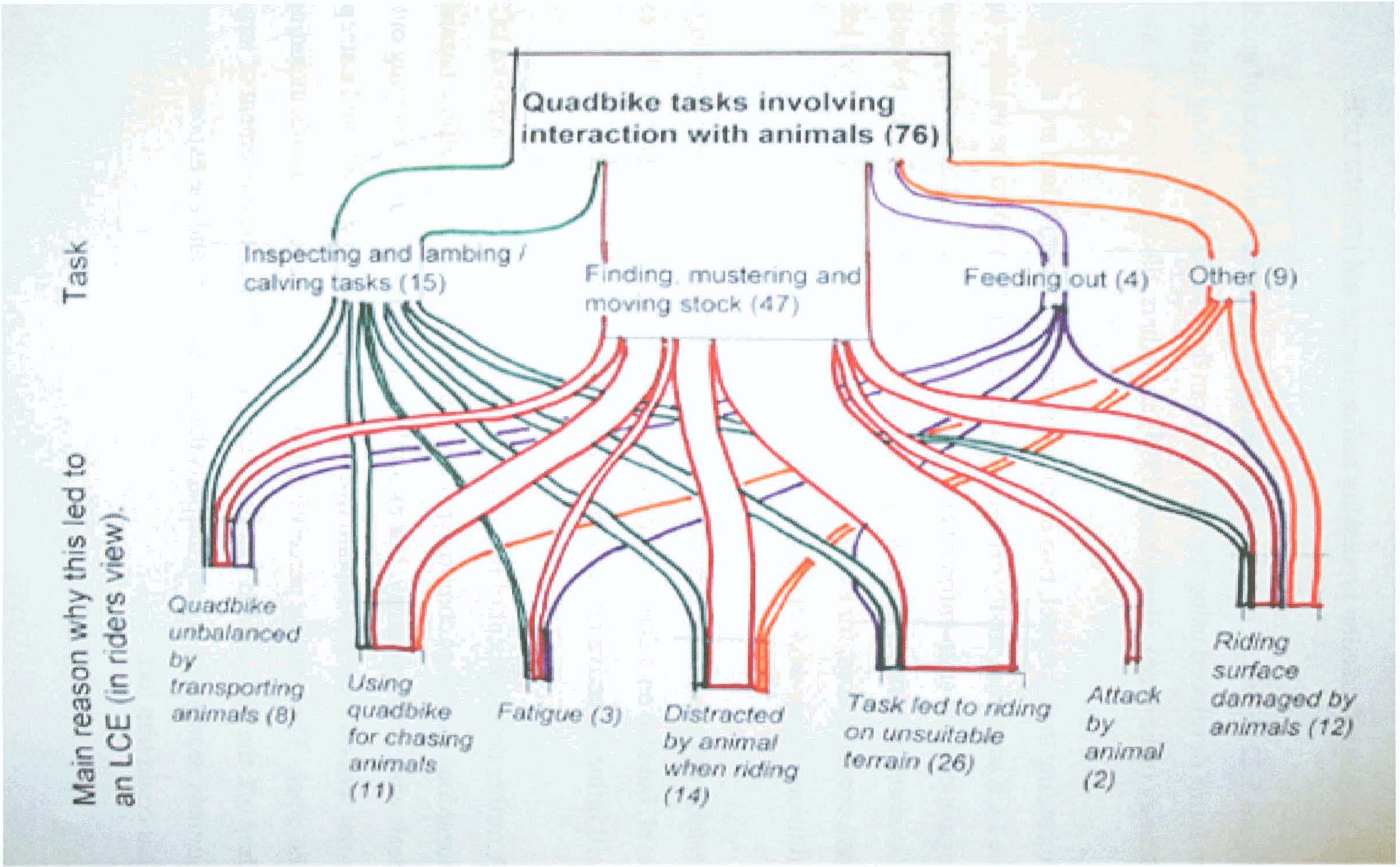

Figure 5.21 Taxonomy of events for LCE while doing tasks involving interaction with animals

The above taxonomy is a useful device for describing sequences of events, immediate risk factors such as fatigue and indicating certain active failures such as choosing to use the quadbike rather than the dog to chase sheep. However, it does not offer perspective on the distal decisions and factors that influenced those sequences of events - the latent risk factors, the personal characteristics of the rider and his/her information processing before, during and after the LCE.

Figure 5.22 shows an interactive and information processing model of quadbike LCE on farms developed using the findings from this study, and building on the work by Bentley (submitted), Slappendel (1995) and others, discussed earlier in this chapter.

According to this model, two extra categories of Latent Failure are acting distally on the LCE scenarios, firstly extra-organisational influences on the industry such as regulations and state-enforced employment conditions. And, secondly personal decisions (effectively small-scale management matters) that can have significant long term consequences; for example, the decision to take on a second waged job in addition to their work at the farm.

Natural environmental factors are taken into account not only at a planning (latent) level, but also on a daily (active) basis. A shower of rain or darkness, for example, will influence active failure factors and also post-injury factors.

A further development of the model is the recognition that for quadbike LCE the hazardous situations comprise not one hazard, but a flow of multiple hazards being dealt with simultaneously. For example, a rider with passenger carrying out a three point turn on a steep mountain track with a big drop on one side and a steep bank on the other. The operator perceives and understands several hazards including: the drop off, the bank behind that could tip the quadbike, the movement of large skittish animals nearby, the hot engine parts that could bum, and the exposed wheel arches that could trap feet.

Sequences of interacting hazards are also found in these quadbike LCE. For example, the destabilising of the machine by hitting an unpredicted surface change (USC), but the rider then not being able to regain full control due to the layout and detailing of the controls. Clothes snag, boots jam in gaps and the thumb throttle is sometimes inadvertently activated by the knee, an animal or a passenger. This causes delay and/or distraction. Where there are also risk factors such as steep drops, banks or obstacles close by while the rider struggles to regain full control, an LCE can occur. The terminology in the information processing has been changed slightly therefore to reflect the multiple hazards being dealt with by the information processing resources.

Within the ***active*** factors section, ***animal and passenger factors*** have been added to reflect the critical role that these third parties play in many LCE in these studies.

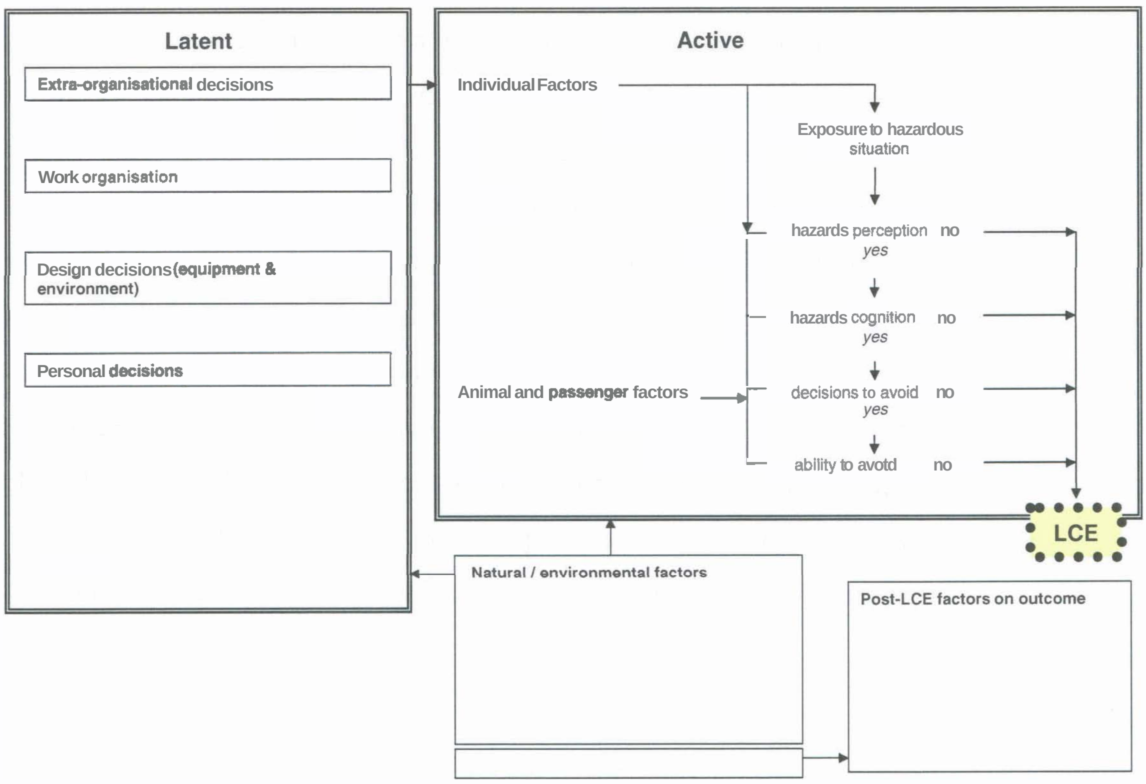

Figure 5.22 Interactive and information processing model of quadbike LCE on farms

Figure 5.23 shows an analysis of the 76 LCE involving animals using this model. Notable amongst the latent factors are the failure of management strategies in work organisation during the busy periods (n=17 cases) to plan for sustainable operations without build up of excessive fatigue that contributes to LCE. The purchase of quadbikes with undesirable features that contribute directly to LCE (n=15) is prominent a poor design decision, and the use of the quadbike without having gained adequate understanding of the machine through training and familiarisation is also highlighted under Personal Decisions.

Individual factors commonly at play in these LCE include watching the animals rather than the route being ridden (n=17), exceeding appropriate speeds for the conditions (n=14), and being caught out when on new terrain or using new equipment with which they are not sufficiently familiar (n=13).

The findings logged on the information processing section of the model reflect a number of important effects. In over a third the rider did not see the hazard(s), in large part due to the divided attention of watching animals while riding (n=17), but also due to the Natural / Environmental factor of long growth concealing holes and obstructions (n=13). In 17 cases the hazard(s) was perceived and understood but the decision to avoid it was not taken. Reasons for this included fatigue, and the rider electing to take the risk to save time when under pressure of either their own or the organisation's making. In just under one third of the cases (n=23), the rider perceived, understood and decided to act but was unable to avoid the LCE through factors including latent inadequacies in the quadbike design (braking, handling, suspension), excessive speed and hard ground that induced sliding.

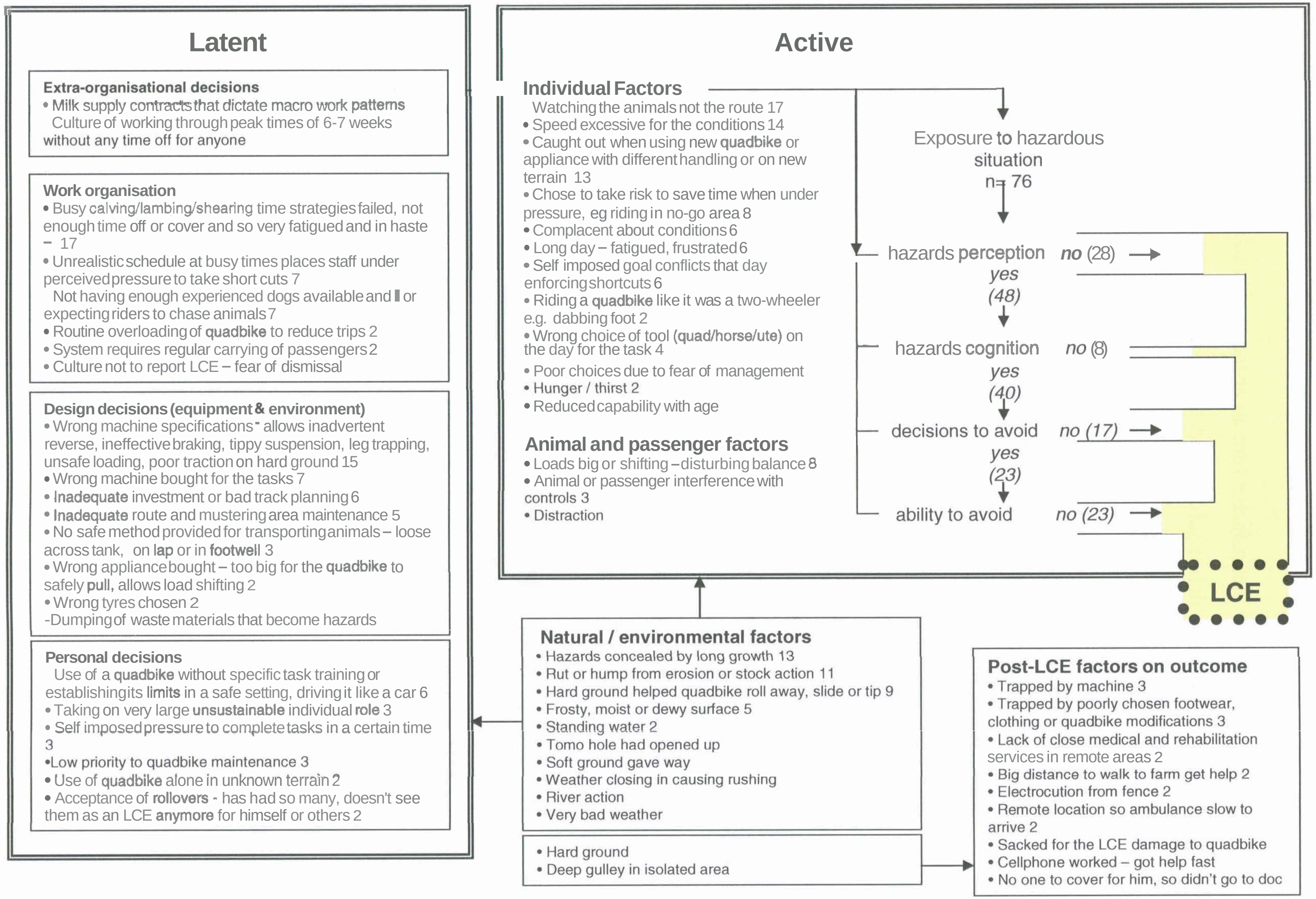

Figure 5.23 Interactive model showing risk factors in the 76 LCE involving animals

5.4.6.2 Risk factors in spraying

Figure 5.24 shows an analysis of the 10 LCE where spraying using the quadbike was being undertaken.

Notable amongst the latent factors are an absence of established safe procedures to the spraying tasks which would protect inexperienced riders, and the de-stabilising effect of the equipment ensembles.

The personal decision to take on these tasks without being fully cognisant of the capabilities and characteristics of the quadbike mounted or drawn spraying systems also features highly, and interacts with the Active factors where the rider is keen to save time but fails to understand the risks involved. In comparison to the analysis on working with animals, there are relatively few Active factors at play in the LCE according to this model other than this. It indicates a substantial mismatch of equipment to the tasks concerned. The spraying systems add shifting weight above the centre of balance of the machine, or very substantial loads on unbraked trailers, further exacerbating the pre-existing weaknesses in quadbikes for farm work. Riders do not need to contribute much in the way of Active factors on the day to produce an LCE.

The findings on the information processing section of the model indicate that hazard cognition is low; the systems appear to be poorly understood as well as error-intolerant.

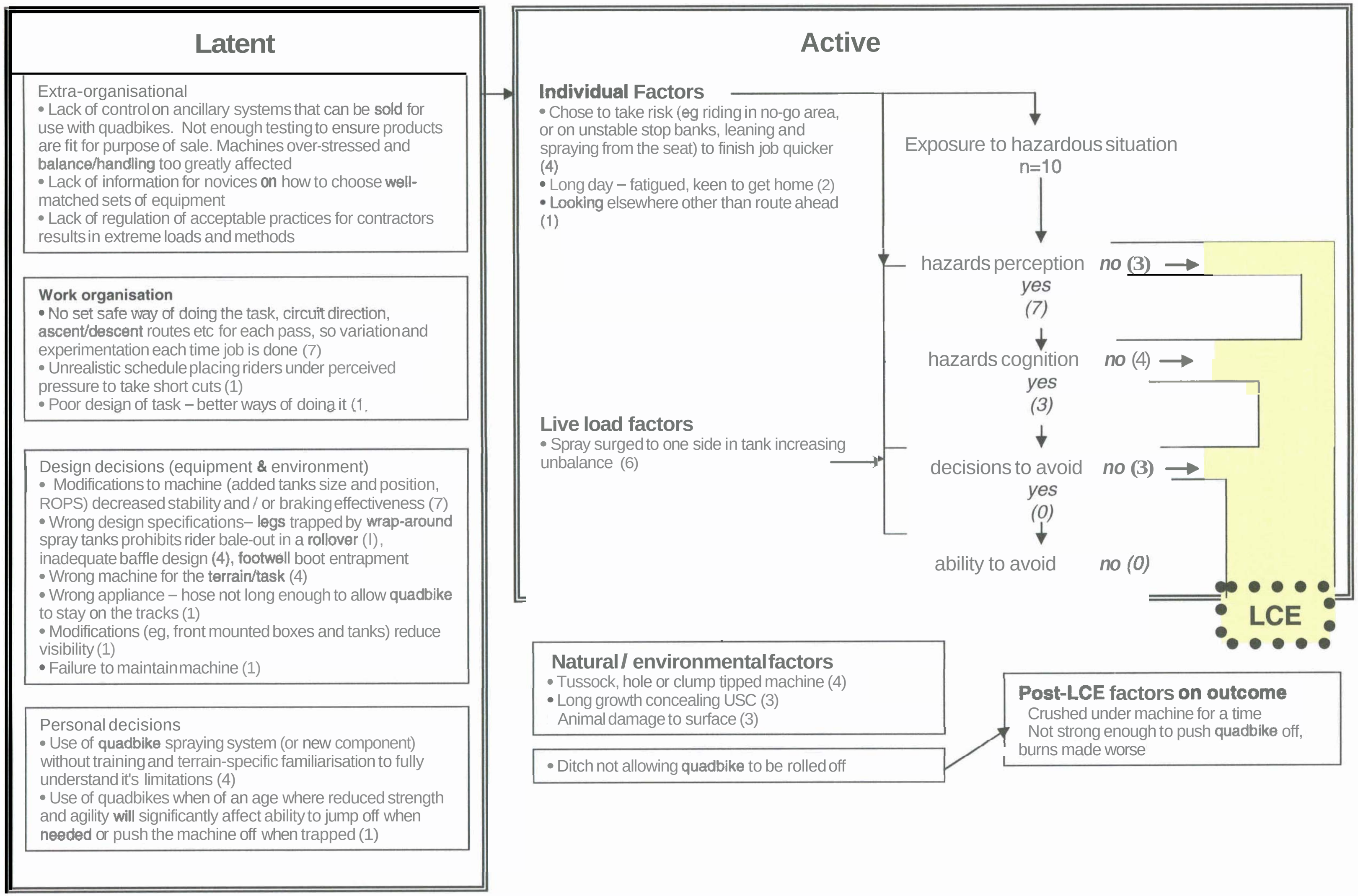

Figure 5.24 Interactive model showing risk factors in the 10 spraying LCB

Common interactions of factors represented in the model include:

1	Inexperience with quadbikes and/or quadbike mounted spray systems with
2	Unpredicted surface changes such as hard clumps or tussocks lifting a wheel
3	Surging of fluid in the tanks – further destabilising the machine

1	Spraying across hillsides (known as sidlings) with
2	Dry lumpy conditions
3	Ground previously grazed when soft by heavy animals who have churned it up
4	Wheel on uphill side contacts significantly less yielding dried mud and rides up over it – rather than squashing it

1	Inability of quadbikes to pull away again on steep slopes once they have stopped, as they do when spot spraying, with
2	Touching back brake (inexperience) as it slides backwards
3	Surging of fluid

In all these cases, age-related reduction in strength and agility interacts by making riders less likely to bale-out, but also less likely to be able to push the machine off once trapped under it.

5.4.6.3 Risk factors in fencework

Figure 5.25 shows an analysis of the 10 LCE where fencing materials were being carted using: rack mounted boxes, fixings directly onto the quadbike racks, on a trailer drawn by the quadbike, or a combination of these. None of the trailers had brakes.

The most common latent factor according to the model was routine overloading. The next most common, and allied latent factor, was using the wrong machine for the job. The riders were either using a cheaper quadbike than was needed for safely carrying the loads required, or trying to get away with just using a quadbike when a more expensive six-wheel drive vehicle or tractor was actually needed.

The personal decision to take on these tasks without being trained or adequately experienced to judge the capabilities and characteristics of the quadbike when loaded in this way was found to be a major underlying factor in three cases. Even those who were well experienced made serious mistakes in misreading routes and/or terrain. An additional four of the ten LCE involved misjudgements of this kind.

The findings on the information processing section of the model indicate that all but one of the riders carting the heavy loads recognised the hazards, and 60% also understood and acted accordingly; but then found the machine was no longer under their control and they lacked the ability to correct the situation. The weight of the machine combined with steep slopes and slick surfaces resulted in early loss of control in the LCE sequence. Quadbike tyres are designed for soft conditions and perform badly on hard ground, especially when moisture is present.

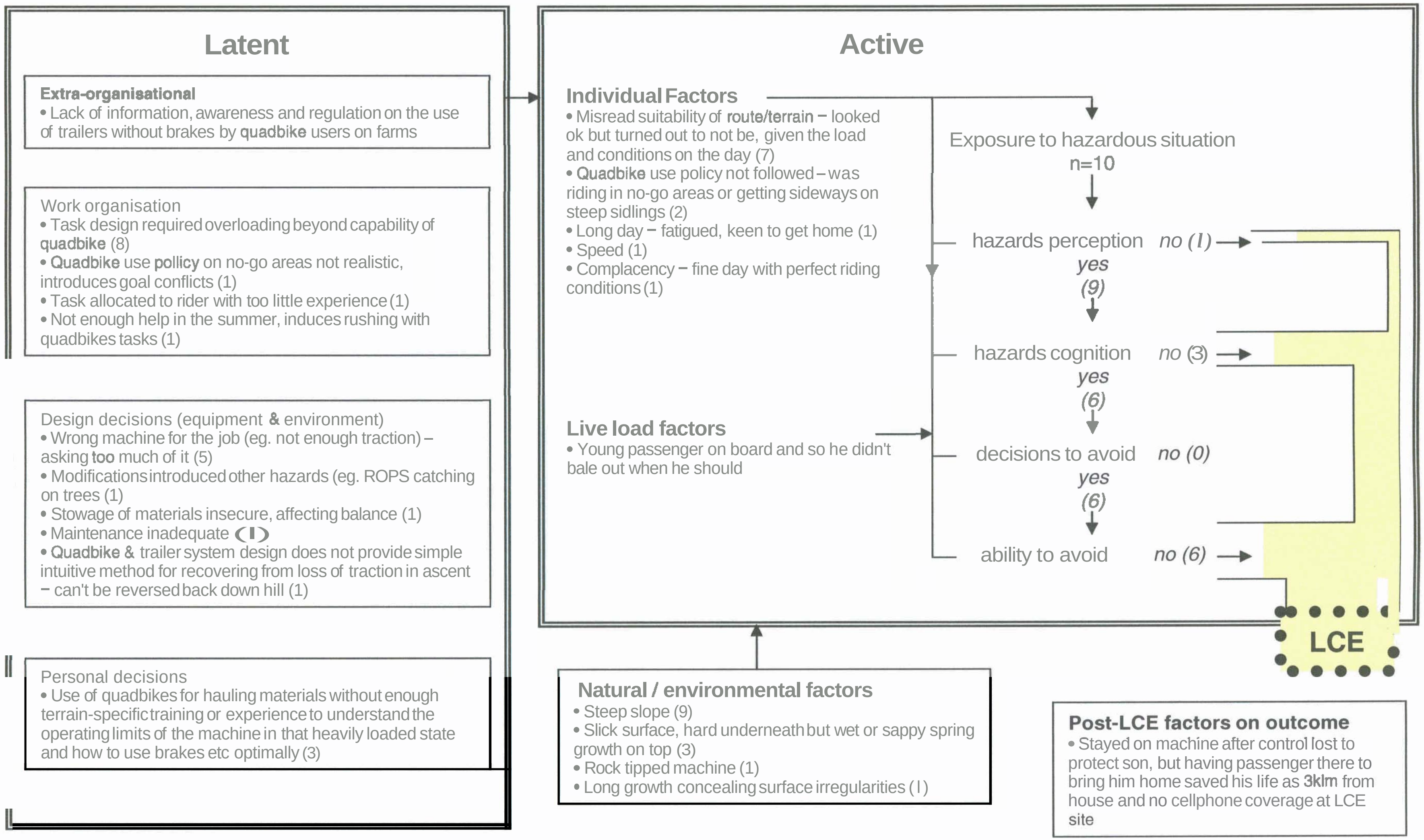

Figure 5.25 Interactive model showing risk factors in the 10 fencing LCE

5.4.7 Risk factors in serious injury cases

The 15 min walk out took two and half hours. They offered to get the chopper in, but I thought it'd cost too much so I waited an hour for the ambulance. I was very stiff by the time they arrived. I had morphine and an hour ride back to town –which given the state of the road was the hardestpan. Due to concerns about my condition they stuck me in the chopper for a ride to Wellington. I had cardiac damage, crushed vertebrae and broken ribs.

Wairarapa Fanner

5.4.7.1 Serious injury LCE event sequences

In all 37 of the serious injury cases the rider was in a riding position, and the vehicle was in motion, immediately prior to the incident. Figure 5.26 shows a taxonomy of the serious injury LCE sequences.

Of particular note is that in 73% (n=27) of the events the machine rolled sideways or tipped (forward or back) while in motion or simply overbalanced when stopped (through the ground subsiding) - then striking the rider or crushing them against the ground. In only 20% did the machine impact hard with something at sufficient speed to throw the rider clear of the machine – the most common scenario for North American recreational riders (Legare, 2002).

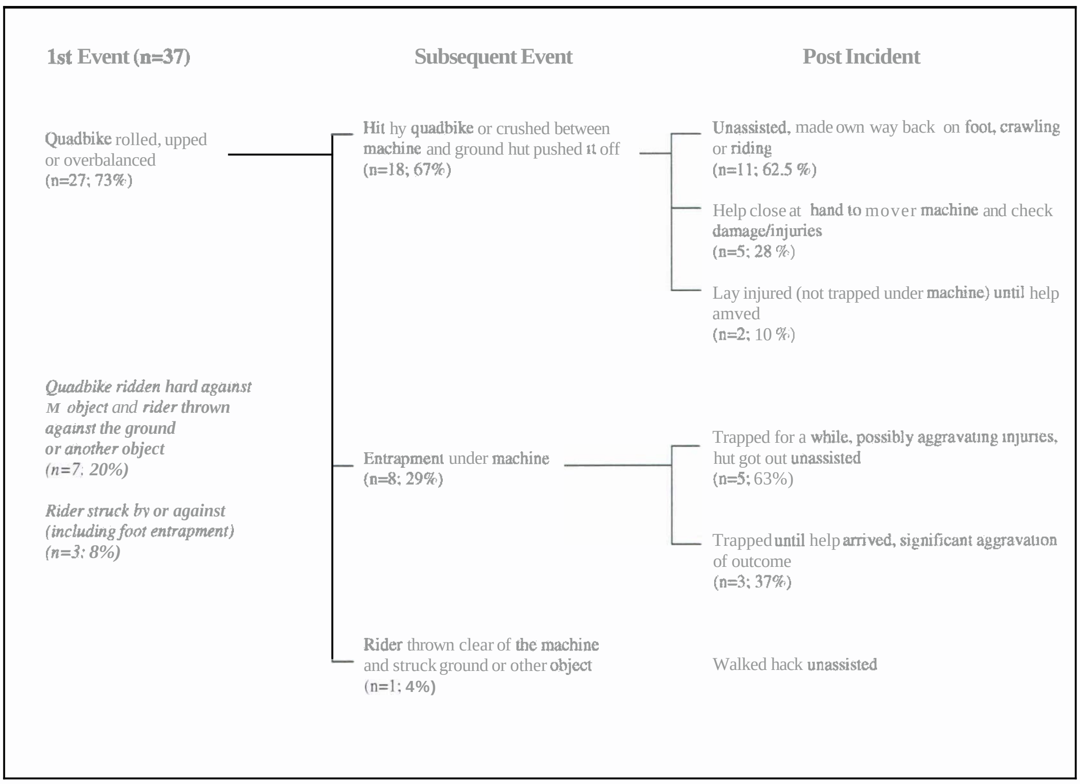

Figure 5.26 Taxonomy of the 37 serious injury LCE sequences

Looking in more detail at the serious injury LCE scenarios analysis in Table 5.17, it can be seen that backward tips occur predominantly on steep country in this study. Forward tips are mostly on the flatter land, where greater speed appears to be a factor as the rider is less wary of the terrain, and they are therefore more likely to drop a wheel into a hole or rut with enough speed to tip the machine.

For simplicity, rolls, tips and overbalancing are grouped under the umbrella term 'rollovers' in the following table.

Table 5.17 Direction of rollovers in serious injury cases – by terrain

Direction of rollover	**Terrain**			
	Flat, undulating or rolling	Strongly rolling or moderately steep	Steep or very steep	Totals
Side	6	1	3	10
Forward	7	0	1	8
Backwards	0	4	5	9
Total	13	5	9	27

Some 26 of the 37 serious injuries occurred with the machine as an injury agent. The rider was trapped under the machine in 14% (n=15) of all LCE rollovers, but twice as commonly (29%. n=8) in the serious injuries cases that involved rollovers. Interventions reducing impact injury and entrapment potential from the quadbike would therefore appear to be a logical target for minimising severity of injuries.

*"I was **pre-feeding** pots for possum control around one o'clock It was **a flat** paddock and I got back on to move onto the next pot. **I can't** remember what happened next but it (the **quadbike**) probably took **off** at speed. It **had clawed** the ground, did a tight circle to the right. I came-to **lying face** down. Leg was pinned by the footplate and rear end. I could reach the horn and controls and **started** the engine but it just **spinned**, wouldn't kick **off**. I tooted the horn until the **battery went flat**. Then it got **dark**. They found me at 6. I lost my calf muscle; Doctor said **another half hour** and it would have been a **lost** leg."*
Taranaki contractor

Analysis of these serious cases by terrain type showed that all three of the most dangerous entrapments, where the rider lay pinned waiting a long period for help to arrive happened on very gentle country. In comparison only two entrapments occurred on the steep or very steep land and in both cases the injured rider was able to eventually get out unaided. This finding is counter to some industry perceptions that hill country is the most likely terrain for fatalities. The slope in fact assists the rider to help roll the weight of the vehicle off their body. Flat land offers no gravitational help, and ditch banks will actively resist attempts to roll it off.

This has quite probably been a critical element in a number of cases where riders and their passengers have drowned in just a few inches of water. (OSH, 2001).

"You don't come off on the steep stuff 'cos you're concentrating.
The spills are on the easy ground where the concentration is elsewhere".
Farmer. Southland.

5.4.7.2 Common factors - haste and secondary visual tasking

"ATVs are not designed for people in a hurry'"
Northland farmer

Haste was found to be a factor in the LCE with serious injury outcomes more commonly than in the less serious cases. This warrants further research of speed in off-road vehicle injury LCE, as the New Zealand experience with road traffic injury links severity clearly to speed.

There are a wide variety of reasons given for the haste. These include lack of time due to delays earlier in the day with stock, bad weather, equipment failures and staff or family illness. For some people working in isolated areas, rare and valued social excursions are the motivation. In one case the farmer admitted that he jacknifed and rolled his quadbike chasing a ewe because the big Fertiliser Company who supplied him were throwing a free party for their customers in town that night and he had no intention of missing it on her account. Those working alone also understandably indulge in personal games to entertain themselves. A farmer who was breaking in a property in a remote part of the Wairarapa was returning from one of many fencing trips to that far corner of the farm and rolled his quadbike while trying to break his record time for the trip.

Secondary visual tasking is used in this chapter as an umbrella term to describe the phenomenon of the rider while in motion looking away (e.g. to look for a colleague or check stock in an adjacent paddock) from the essential tasks involved in riding the quadbike, resulting in recognition error (Noy, 2001). The term was used in preference to Concurrent Visual Task distraction (Bentley & Halsam, 2001; Bentley, submitted) for this quadbike LCE study, as in most cases the tasks were mutually exclusive. They could not be done concurrently. The riders were aware that they needed to be reading the micro-terrain ahead almost constantly, but took the risk of dropping this primary task (without stopping the machine), assuming the route ahead to be free of features requiring response actions, to look elsewhere for a significant interval. The hazard was not perceived, or perceived fully, as a result.

5.4.7.3 Risk factor combinations and serious injury

"You get used to knowing when it's time to get off."
Farmer. Taihape, central North Island.

Table 5.18 shows the most common pairs of risk factor combinations appearing in at least 5% of all the LCE, or three of the serious injury LCE cases. At this level of analysis the spread of identified risk factors is very wide and the incidence counts are very small. This reflects the wide range of quadbike applications on farms.

The findings show the most common combination for all LCE to be working on routes considered by the rider as marginal for quadbike use, with a load (n=21, of which three were serious). However, other combinations (examples shown in **bold)** where speed/haste is involved show a much higher proportion of serious injury cases resulting.

Table 5.18 Most common pairs of risk factors and severity of injury

Factor 1	Factor 2	All LCE	Serious injury LCE
Use of marginal routes	Loads – big, shifting, badly placed or unfamiliar	21	3
Use of marginal routes	Unpredicted Surface Changes	14	3
Secondary Visual Task	Unpredicted Surface Changes	13	4
Use of marginal routes	Inexperience with quads	13	3
Haste	Unpredicted Surface Changes	11	3
Lack of time to react, due to speed of machine and/or speed of LCE	**Equipment – Task mismatch**	**10**	**4**
Use of marginal routes	Equipment – Task mismatch	10	3
Rider fatigue	Poor choice of route doe to feeling under pressure	10	2
Lack of time to react, due to speed of machine and/or speed of LCE	Unpredicted Surface Changes	10	2
Haste	**Lack of time to react, due to speed of machine and/or speed of LCE**	**9**	**3**
Secondary Visual Task	Latent failures in design (leading to easily repeated errors)	9	2
Loads – big, shifting, badly placed or unfamiliar	Inexperience with quads	9	1
Unpredicted Surface Changes	Equipment – Task mismatch	8	
Loads – big, shifting, badly placed or unfamiliar	Equipment – Task mismatch	8	

This table also indicates the importance of the underlying organisational factors in the LCE investigated. Intervention measures that could arise in response to these organisational factors include: ensuring that the farm has the right tools for the jobs, having clear policies on no-go marginal areas, recognising that work pressures influence route choice, and ensuring sufficient experience has been gained before allowing younger staff to work unsupervised.

An examination of combinations of three factors together present in individual LCE, reveals a very wide spread of combinations. Table 5.19 shows even the most commonly interacting set of three risk factors appearing in less than 5% of all LCE cases investigated. However, the presence of speed, haste and the carrying out of tasks under pressure (shown in **bold)** are evident in those with the most serious injury outcomes.

Table 5.19 Most common combinations of 3 factors in an LCE that appear in at least 5 LCEs or 2 Serious injury cases (156 LCE in total)

Factor 1	Factor 2	Factor 3	Incidence among all LCE	Incidence - Serious cases (n=37)
Haste	Unpredicted Surface Changes	Lack of time to react, due to speed of machine and/or speed of LCE	7 (4.46%)	2 (5.4%)
Inexperience with quads	Use of marginal routes	Loads – big, shifting, badly placed or unfamiliar	5	1
Haste	**Rider fatigue**	**Poor choice of route due to feeling pressured**	4	2
Use of marginal routes	Rider fatigue	Unpredicted Surface Changes	3	2
Use of marginal routes	**Equipment – Task mismatch**	**Lack of time to react, due to speed of machine and/or speed of LCE**	3	2
Haste	**Equipment – Task mismatch**	**Poor choice of route dne to feeling under pressure**	3	2
Haste	**Equipment – Task mismatch**	**Secondary Visual Task**	2	2
Unfamiliarity with terrain (new or altered)	Inexperience with quads	Use of marginal routes	2	2
Haste	**Secondary Visual Task**	**Lack of time to react, due to speed of machine and/or speed of LCE**	2	2
Rider fatigue	**Equipment – Task mismatch**	**Poor choice of route due to feeling under pressure**	2	2

This very wide spread of factor combinations reflect the diversity of LCE scenarios reported around the country. There is no tightly defined cluster of interacting factors to be neatly targeted by injury prevention exercises, hence a broad-based programme of countermeasures is likely to be needed to achieve meaningful success across the industry.

5.4.8 Interventions

5.4.8.1 Introduction

To achieve the highly participative research method that was needed to explore system-wide risk factors, the scope of the study needed to embrace remedial interventions too. This method yielded a rich dataset of potential interventions at various stages of refinement which expanded the body of knowledge in this area considerably. A summary of the final intervention matrix is shown in Table 5.20. It shows a marked emphasis on pre-event (or primary) interventions. The interventions identified in the literature prior to this study, were leaflets & videos (including guidance on skills and regular maintenance), visual warnings, ROPS, skills training and helmets.

Intervention priority for each intervention level is indicated, those that could be achieved almost immediately and with easiest implementation are shown in bold.

Table 5.20 Findings summary - potential interventions

Intervention level	Pre-LCE (Primary)	LCE (Secondary)	Post-LCE (Tertiary)
Government	Encouragement of concept redesign.	Support national investigation database.	Support research for solutions. Improved rural access to medical care.
Regulatory environment	Control the design of accessories and limit the specifications of machines that can be brought in to keep out undesirable features. Restriction of load carriage by design. Warrant of Fitness for quadbikes. Licensing of machines and riders.	Test modifications Formalised and pooled investigations of LCE. Point load avoidance.	Require new machines to have auto Search & Rescue in-built alarm
Social environment	Media campaigns timed to annual risks.	Raise awareness of older users on the need to bail out.	Maintain regular family contact during the day.
Organisation	Formalisation of unmarked routes. Choosing the right machine for the job (eg 6-wheeler for fencing). Planning for fatigue effects. Managing peak workloads. Realistic goal-setting. Keeping enough good dogs More track investment Optimise track design	Consider entrapment features when purchasing.	Formalise Search & Rescue policy.
Physical environment	Prioritise track maintenance. Shorter grass on routes across paddocks. Soil/track erosion control. Fence line planning to accommodate quadbikes better.		Improve Tele-communication coverage. Improve awareness of new technology.
Cargo / task	Improved spray equipment design. Use of customised trailers. Control of cargo width.	Make tank baffles mandatory. Lowered stowage. Safer choices of trailer.	Reduce entrapment by design and new products.
Machine	Creeper gear. Reverse gear warning beeper. Throttle protection. Lights optimisation. Effective park brakes. Better maintenance. Remote operation device.	Innovative roll-over protection. Swivel couplings. Throttle de-sensitisation	Air-bag linked alarm
Rider	Specific young rider education. Education on visual distraction. Expert user video. Technique tips – biomechanical.	Training on bailing-out. Easy-doff footwear.	Personal GPS alarm. Education on 1st aid.

5.4.8.2 Countermeasures

When set alongside the countermeasure strategy areas traditionally used in road vehicle injury prevention (Haddon, 1973) in Table 5.21, it is clear that the nature of the vehicle and its use in New Zealand limit the intervention options that could act during the Crash (LCE) phase.

Table 5.21 Haddon 10 Countermeasures list and potential interventions

	Haddon 10 Countermeasures	**quadbike LCE intervention – examples from the study**
Pre-Crash (LCE)	Prevent marshalling of initial form of energy.	Use tools better matched to the job, eg. use dogs to chase sheep in gullies not quadbikes.
	Reduce amount of energy marshalled.	Control loads, govern speeds.
Crash (LCE)	Prevent release of energy.	Downhill tracks with run-offs allow an LCE to be brought back under control, but LCE are not always on downhill slopes or the route demands traversing.
	Modify rate of spatial distribution of energy from its source.	Invent active re-stabilisation device to counter roll - not tried yet and would be hard to develop as a retrofit to the 70,000 existing machines. More use of baffles in tanks to stop spray fluid surge – some being made but not evaluated yet.
	Separate in time or space energy released and susceptible structure.	ROPS – very mixed evaluation findings and manufacturers actively campaigning against their use. Full running boards have replaced footpegs and provide a solid platform to push against as the machine rolls onto the rider which may take some of the impact out – some low price models no longer have them though. Unevaluated.
	Separate them by material barrier.	Aiibags – un tried.
	Modify the damaging contact surface.	Remove sharp accessories and loads that can injure by point-impact to leave rounded surfaces as intended in the original ATV concept – this is unlikely to be done as farmers need to modify all vehicles to carry various things.
	Strengthen living structure susceptible to damage.	Helmets – design not ideal yet and uptake poor; torso is the area that actually needs protecting most anyway. Boots with the needed ankle protection are also hard to slip off, which is an advantage if trapped by the leg under the machine.
Post-Crash (LCE)	Move rapidly in detection and evaluation, limit damage extent and spread.	Farm policies for checking staff, better communications, first aid, quick diagnosis.
	Rehabilitation.	Improved rural access to medical care.

5.4.8.3 Pre-LCE (Primary)

Table 5.22 shows the interventions developed to act upstream of the LCE arranged by risk factors which they indicatively address.

Table 5.22 Potential interventions that act Pre-LCE

Interventions	Risk factors
1. Improved track maintenance. 2. Keeping grass and undergrowth short so that the surface on commonly used routes across paddocks is revealed for riders. 3. Surface water movement managed to minimise erosion. 4. Always use same route across untracked areas to monitor erosion. 5. National media releases on hazards of USC each year timed to coincide with the main flush of new grass growth that will conceal holes.	Unpredicted Surface Changes (USC)
6. Invest more in tracks to reduce exposure time on marginal country.	Use of marginal routes
7. Require implements, racks, protective bars, cabs, etc to be tested for use with specific quad types and sold on that basis. Farm to have policy that minimises the need for improvised carriage of live loads. 8. Add baffles/compartments to minimise fluid movement in tanks and shifting of loose loads such as tools and fencing staples within boxes. 9. Use routes that offer straight run-outs at the bottom of any slopes. Don't attempt changes of direction on slopes. 10. Racks need to be tested for ability to take loads without unloading traction from front wheels in ascent. Loads should not act behind the rear axle. 11. Place spray fluids as low as possible towards the centre line of the axles. If quads have to be used, filling the tyres or an added double tyre with the fluids – as currently done with tractor tyres for stability, could be trialed.	Loads – big, shifting, badly placed or unfamiliar
12. Long term development of vehicles that don't need modifying or to be operated routinely outside their design parameters. 13. Riders to be made aware of the effects of modifications and implements on stability, entrapment and injury outcomes from possibly increased point loads acting on the body. 14. Encourage buyers to select the right type of machine for the job. Eg. 4WD where it is needed. 15. Encourage manufacturers to offer machines that don't require weight shift at low speed for that section of the market who don't want, or aren't capable of, Active Riding. Criteria may include: lightweight 2WD for ease of steering by older rider lacking some upper body strength. 16. Transport bulk fluid by a separate vehicle to limit tank volume needed on quad. 17. Add creeper gear with steering head tightener to enable feeding out with both hands free. Also useful for walking the quad off steep unrideable hills. 18. Machine not maintained fit for task – introduce a WOF and off-road machine licensing.	Equipment – Task mismatch
19. Encourage the uptake of basic training to give new riders essential skills, such as effective weight shift techniques. 20. Investigate ways to increase the confidence of young and/or inexperienced riders to know and work within their personal limits. 21. Introduce licences for off-road riders.	Inexperience with quads
22. Education for farm workers on the increased risk through fatigue at physically and mentally demanding times such as lambing. 23. Manage farm operations to minimise peak workloads. For example: breed out ewes with birthing difficulties to reduce the frequency of the lambing beats needed. 24. Add power steering for all machines to be used on rough ground.	Rider fatigue
25. Educate riders on the likelihood of LCE when looking away from the ground ahead of the quad eg. watching stock movements whilst riding on an unpredictable surface.	Secondary Visual Task
26. Inform farmers on the importance of setting realistic work schedules for themselves and others. Have clear strict policy on no-go marginal areas on the farm to avoid goal conflict and hence rushing.	Haste
27. Implement attachment systems that do not afford 'snap roll' leverage of the quad. Swivel couplings in the drawbar line for example. 28. Minimise fluid movement in tanks and shifting of loose loads such as tools and fencing staples. 29. Lower and centralise holding positions of fluids.	Lack of time to react, due to speed of machine and/or speed of LCE
30. Issue very clear instructions with no goal conflicts especially for new employees.	Making poor choice of route due to feeling under pressure

31. The planning of new fence lines to take quad use into account Guidelines giving minimums for angles and clear path widths may be beneficial. 32. Managing respectful use amongst users on the property.	Unfamiliarity with terrain (new or altered)
33. Make riders aware of the potential for over-familiarity or complacency in riding at times of high usage with insidious increases in risk-taking.	Elevated perceptions of personal safety
34. Make available kits for modifying all machines to alert rider to the quad being in reverse gear - reducing LCE through inadvertent reversing. 35. Require throttle protection to be provided on all models imported to reduce inadvertent operation by the knee when getting on and/or turning hard right. 36. Avoid set up arrangements where trailed implement, rear axle & tyre assembly or load is critically wider than the front of the machine in view of the rider. Striking obstacles after the rider has passed them may well add surprise and speed to the LCE. 37. Park brakes often fail and machines run away down hill. They should have ratchet multi-stage action like car hand brakes - many older quadbikes have single position cable brakes that do not allow more tension to be added as cables stretch between servicings. Transmission lock as brakes for automatics. Engine lock as riders weight comes off the seat or footpegs suggested. 38. Re-engineer to exchange high top speed for more low speed torque that will improve pull and traction on hills. 39. Wider wheelbase, limited slip differential and an active system of counterbalancing (as with rough terrain forklifts Cooper, 1998).	Latent failures in design (for New Zealand farming applications)
40. Initiate a national WOF-type system for quadbikes to: protect riders better from machine failure and enable owners to demonstrate willingness to maintain equipment responsibly. 41. Formalise maintenance and daily/weekly checking on farms.	Equipment failure
42. Make riders aware that newer machines do not necessarily have better stability than older models. Also that 2 apparently identical machines can handle differently.	Unfamiliarity with the machine (new or someone else's)
43. Develop and distribute a DVD / video showing practical strategies for getting out of common difficulties. 44. Promote especially amongst younger riders at schools at colleges while they are more impressionable; make it an interactive CD game with internal rules that agree with actual best practice.	Not knowing how to get out of a particular tight situation
45. Promote practice – 'don't go down a slope you haven't already been up'. 46. Desensitise throttle to make it easier to maintain slow speed control on steep descents.	Failure to see holes through being in descent (surface appears more smooth)
47. None developed	Over-familiarity with terrain (complacence)
48. Keep enough experienced dogs and allow sufficient time to do the job with the dogs you've got.	Doing the dog's job
49. Rider has to learn not to be too rigid. Straight wrists (or knees when standing) will jar and be injured when you hit a lump, so all joints need to stay soft and slighting bent.	Adopting weak biomechanical riding style
50. Add 'cats whiskers' to front of machine in clear view to indicate the extra width of the following trailed implement.	Not knowing what towed implements will do – their effect on handling
51. None developed	Inappropriate transfer of road b i e skills
52. Remote operation to enable riders to get off and drive it off the hill using the remote throttle controller. quadbikes are more stable with the rider off it than on it.	Not using equipment to full potential
53. None developed	Panic
54. Lights that work. Need to be mounted so that they point where youre going – not where you've been. So handlebars not frame. Also not obscured by the toolboxes and fishboxes invariably placed on front rack.	Route of view obscured
55. Require throttle to be redesigned or protection fitted to on all models imported to reduce unintended operation by animals, loose loads or others on the vehicle. 56. Formally compare twist grip throttle as used on two-wheelers V thumb lever.	Passengers, animal or dogs interfering with operation of quad
57. Formalise a system of easy to remember daily pre-ride maintenance checks with pneumonic as used for tractors.	Changes in quad condition since last in that situation
58. None developed	On unfamiliar (quadbie riding) surfaces e.g. Tarseal or concrete

5.4.8.4 During LCE and Post-LCE

In the above Table the interventions sought to prevent LCE occurring. Once the LCE are in progress, or have happened the interventions listed in Table 5.23 below apply.

Table 5.23 Interventions for reducing severity of injury during and following an LCE

Intervention	Risk areas
59. Educate riders on the need to have **mentally** rehearsed their bail out plan before entering a high risk scenario. 'Better to get off than be thrown off as then the machine will follow you. Don't stay with the ride if you are not in control 'throw it (the **quadbike**) away – they're still making them'. 60. Don't use a trailer in high risk scenarios where bail-out maybe needed. It will discourage bail out as a wide one will be directly in the line of escape and likely to cause injury.	Reluctance to bail out at the right time
61. Require manufacturers to formally assess entrapment potential after roll overs on each new machine type – especially on flat smoother country. 62. Require all machines imported to have full running boards fitted that do not offer entrapment either when in motion or after tipping. Fold-up or fold-in mechanisms that permit feet to be pulled away from underneath may be considered. 63. Select boots that have sufficient rigidity to support ankles but don't have features that snag during bale out, and can be kicked off without need for untying if trapped. 64. Accessory designers to consider the need for easy bale out when looking at systems that wraparound the user. [Older style three sided spray tanks have been cited as problematic in this way]. 65. Trailers that jackknife should not be able to offer a pinch point against the quad around the legs, entrapping the rider and stopping bale-out.	Entrapment
66. Investigate ways to reduce point load impact potential on the riders' body by: originally fitted elements [eg. handlebars, racks] and additions [eg. toolboxes, **dogtrays,** spray boom mounts]. 67. Air bags – idea from tussocks 'bags of life' and fish boxes that act as crumple zones to keep the weight off and stop crushing between points of machine and hard ground. Two stage bags – one to prevent crushing, one to lever machine off (**ROBs** – Roll Off Bags). **Entrapments** much rarer in tussock country where big soft balls take the load – use this principle.	Crushing potential
68. Investigate potential for personal **alarm** device that is affordable, works in remote country and can be carried comfortably on the person *at* all times. It should able to be interacted with by both family and search and rescue bodies.	Inadequate communications
69. Adapt the technology already available on road vehicles whereby deployment of the air bag automatically triggers a call for aid. This is the **only** way identified hat the alarm can be raised 70. Enhanced RICE-Type **first** aid and basic diagnostic knowledge so that people get better at judging when an injury will resolve fully without professional intervention, or when delay in getting to the doctor will be costly. 71. Improve rural access to medical *care*	Delay in getting medical attention

5.4.8.5 Task-specific interventions

Amongst the 72 interventions shown in Table 5.22 and Table 5.23 are generic measures for all quadbike users on farms, while others address specific system weaknesses in specific tasks. The following two Figures 5.27 and 5.28 show examples of interventions that relate directly to the most important task-specific risk factors in firstly stock-related work, and secondly, spraying.

As has already been noted, the majority of the interventions developed relate to pre-LCE factors. The interventions aimed at these upstream latent factors are designed to also act on the natural/environmental and post-LCE factors. For example, improved erosion control will reduce the likelihood of a rider dropping a wheel into a hole (tomo) that could otherwise have appeared overnight, and which might ordinarily have been seen as an uncontrollable factor contributing to an active failure. Similarly, improved rural access to medical advice would generate much earlier diagnosis. The costs and travel involved result currently in a two week delay between LCE and seeing the doctor for strains/sprains to be considered normal.

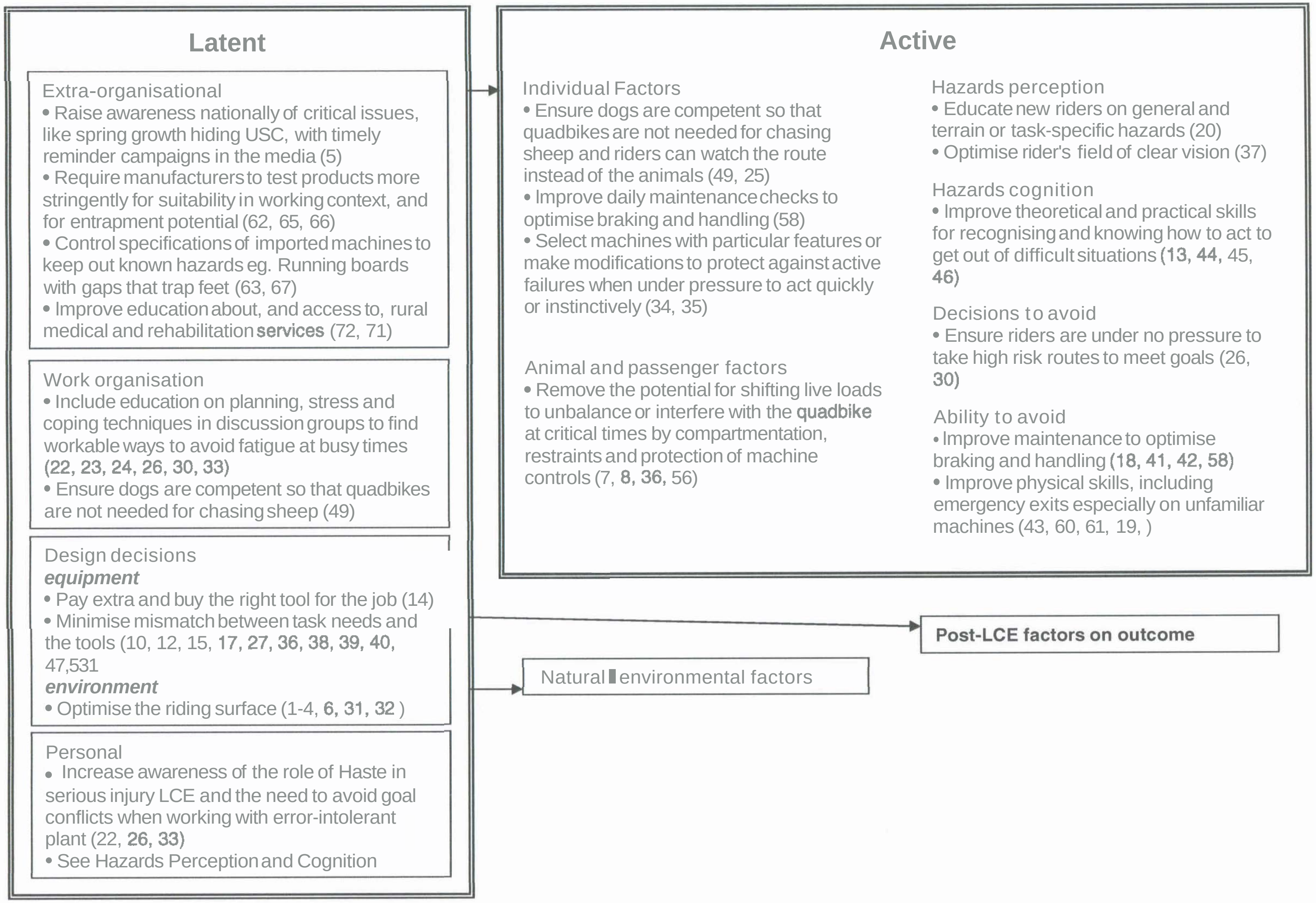

Figure 5.27 Key interventions (numbered) plotted on model for tasks involving interaction with animals

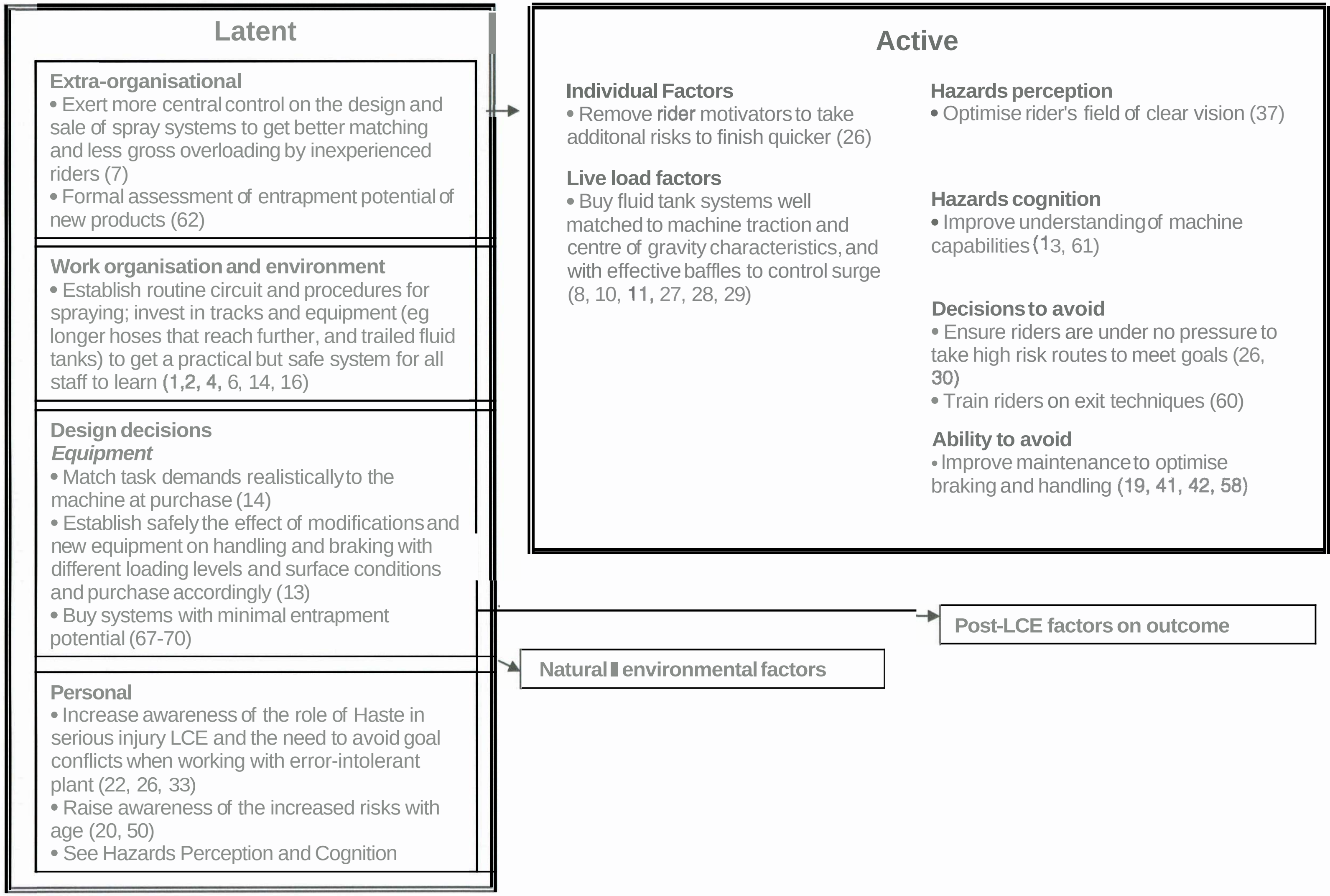

Figure 5.28 Key interventions (numbered) plotted on model for spraying tasks

5.5 Discussion

The aims of the research reported in this chapter were to:

- Develop a suitable investigative method for the analysis of quadbike LCE on New Zealand farms
- Identify risk factors for LCE and their interactions
- Identify potential interventions that would reduce the incidence and/or severity of quadbike-related LCE on New Zealand farms.

5.5.1 Investigation method

The use of an ergonomics or systems approach for investigating the problem of quadbike LCE on farms allowed consideration of LCE from the perspective of the interactions between the user, their equipment, the task and their physical and social environment. It is the first study to apply a systems perspective to quadbike LCE, and made possible the identification of latent organisational risk factors.
The method proved consistently workable on site, and was flexible enough in administration to accommodate the unique conditions encountered at each farm. In particular, the investigation sheet developed for this study generated consistent organisational and social level data which provided a unique perspective on why the decisions taken by the riders which led to the LCE made sense to them at the time.

The information processing component in the model developed during the study provided valuable understanding relating to the interactions of the risk factors.

Considerable efforts were made on site to seek corroboration of verbal accounts by convergence of data sources. Testimonies from colleagues and complimentary archival sources were sought. Reliability of recall was also predicted to improve using the scale quadbike model method, and the experience of the researcher in this study supports that. The possibility remains that the use of props may enable subjects struggling to remember, to create in their mind a more logical version of events, but one that is still inaccurate (personal communication Lobb, 2005). Despite this however, the continued use of such devices in the forensic disciplines suggests that there is overall benefit in practice. To address this limitation triangulation of data sources was sought to further test the accounts offered. This approach is well established 'test[ing] the same variables... but [using techniques] with different methodological weaknesses' (Webb et al., 1966).

A key focus of the research that emerged was the questioning of why the decisions of the riders involved in the LCE 'had made sense to them at the time' (Dekker, 2003). This philosophical approach not only made sense to the researcher, but also proved robust in appealing to the study participants, which further encouraged the exploration of the context of the events that day. Slappendel (1995. 243) had noted that although ergonomics approaches have gained general support in New Zealand in theory, field methods to date have struggled to collect factor interaction data. The event charts, and interactive quadbike LCE model, that were developed for the analysis advanced the available methods for ergonomics field work in this regard.

5.5.1.1 ACC records

The study method provided an opportunity to directly compare ACC records with on-site investigation findings. The findings raised concerns about the quality and reliability of centrally collected records that are used extensively by the injury prevention community, government and the industry. The accounts of LCE recorded in the ACC data rarely matched the investigation findings in important details, and in 10-15% of cases bore no resemblance whatsoever. On the basis of this work, conclusions drawn from future narrative content analysis of this database should be stated clearly as tentative, and further verification sought before significant policies are formed from this evidence base.

Although not part of the formal study, the subjects were asked what had motivated them to misreport. The claimants reported a need to 'tell ACC what they wanted to hear' in order to get payments that they (and possibly their clinician) saw as justified. For example, some accounts given of the incidents therefore migrated away from the true accounts of slower onset MSD problems with no single clear cause, towards more simple acute struck-by / struck-against explanations that they knew ACC would accept for payment. For example, one rider had previously had claims rejected by **ACC** that she felt were valid, and so when she came to report the **LCE** in question she simply gave an account based on a completely different incident that another family member had successfully claimed for. In some regions this was more marked than in others, which subjects attributed to the differing approaches of the local **ACC** offices. Some were reported to be much tougher than others to deal with.

5.5.2 Risk factors and event sequences

5.5.2.1 Rider/individual factors

The analysis of employment status showed farmers (those owning or leasing the farm) to be over-represented amongst LCE subjects. The reason for this may simply be that the farmers spend more total hours on the machines. A recurrent suggestion from the farmers themselves however, was that their role was also subtly different. As they carried ultimate responsibility for seeing that everything got done, many felt they were more likely to find themselves under pressure and needing to accept greater risk to complete all the work for the day. At times when stock are being born there is work that cannot be left for another day. This is an interesting line of enquiry for future study. Quantitative data logging methods could usefully be used to track machine usage and converge with subjective reports. Objective data are also needed on exposure hours spent riding by contractors, who in this study show alarming patterns of work.

Other published studies have identified financial stress as a factor in farm injuries (Kartunnen, 2003; Simpson et al., 2004) and further study is warranted to see if these factors are similarly influencing the incidence or severity of quadbike LCE in New Zealand. The finding that serious injuries are clustered around the 46 year old age group would appear to support the industry concerns that middle-aged men with marked business and family pressures are a high risk group.

LCE are more common amongst people of retirement age than has been noted in North American studies. The findings of this study raise the question of whether the riders' expectations match the characteristics of the machine adequately. This group is looking for a machine that is inherently easier and safer than a two-wheeler. The 'affordances' appear to be misleading for this section of the population at least.

The consistent under-representation of adult women riders in the incident data warrants further investigation. The question of whether this can be explained simply by their riding for less hours and/or on less inherently risky tasks – as suggested (by males) on a number of farms, requires specific observational studies including task analysis and quantitative measures. An on-bike GPS-enabled data logging system with remote download is recommended as one element. A comparative analysis of male and female approaches to difficult tasks would also be needed as the female response in interview to the suggestion that they did not attempt the inherently risky tasks was strongly denied.

The analysis of injuries by type and body region were consistent with those reported in the epidemiological study of ACC data reported in Chapter Two. The serious injuries, however, show a distinct and different pattern with 60% affecting the chest and lower limbs. In all but six cases the machine was being ridden at the time of the LCE, and nearly half of the cases where injuries were adequately specified involved contact with the machine, or crushing between it and the ground.

Further study is needed to investigate this on a suitably large scale, and then if found more widely, assess the mechanisms leading to these types of harm. It is likely that contact is being made with handlebars and other tubular structures such as the ubiquitously added racks and bullbars – which as noted in Chapter One, are counter to the overall design concept of a 'soft, bouncy, fun vehicle'.

The findings do not support the hypothesis that working in isolation automatically increases the likelihood of a serious injury LCE. Balancing influences could be that the awareness of exposure heightens caution, and conversely companionship may encourage greater risk taking, either through bravado/competitiveness or simply as a result of a greater feeling of safety.

5.5.2.2 Temporal and terrain/ground factors

The time of day findings in this quadbike LCE study run counter to preconceptions voiced during the interviews that the highest incidences would centre on dawn and dusk when environmental conditions are known to be most difficult. Parker et al (2002) research with New Zealand forest logging crews highlighted the importance of establishing time of day of incidents within the framework of breaks for each specific occupational group. In their study, the peak of injuries were between 9-10am - the time at which crews were preparing for the first break of the day. Factors in this appeared to be (personal communication): making their way through the forest back to the collection point resulting in a high number of minor injuries, insufficient hydration and nutrition in the preceding 4-5 hours since getting up and fatigue (Bates et al., 2000; Bentley et al., 2005). Reports for minor injuries, considered not worth stopping work for, may also have been filed at the morning break – increasing the volume of forms filled out at this point. Research in other sectors has also found certain risk factors elevated in the first half of the working day. Studies on road vehicle operators (Folkhard, 1997. 199) showed fatigue peaking after 2-4 hours on task (to levels exceeded subsequently only after 12 hours driving).

Further studies are needed to explore the accuracy of risk perceptions of quadbike users on farms. It may be that riders quite accurately assess the ground conditions, but underestimate the risk when multiplying effects of organisational, social, circadian and nutritional factors. As with the loggers there may be patterns linked to nutrition and/or increased travelling at these times, as the binomial distributions indicate similar peaks.

The findings on time of year were contrary in part to popular expectations. The peak lambing and calving periods of August / September are known to involve long hours in poor weather, and incidents linked to fatigue and workload pressures are not surprising. The spike in January, however, was not predicted. That two thirds occur on firm ground suggests that further work is needed on improving the traction of quadbikes on hard, rutted surfaces, especially where moistened by dew, light rain or lush growth such as clover.

5.5.2.3 Vehicle performance factors

The most common activity immediately preceding the events was stockwork which accounted for a little over a third of all 156 LCE. However this covers a wide variety of subtasks, mustering, catching, checking and moving animals of various types and for various purposes. It is of note that 39% of LCE for this task group take place on fairly flat ground, rather than on the hills. The importance of micro-terrain is highlighted by this. The interaction of rutted ground, speed and failure of the mustering rider who is watching the stock as he turns to predict the ruts or humps, is a common scenario in the set of LCE studied.

In the Discussion in Chapter Four, a potential conflict caused by over-ambitious function allocation was identified; the rider has to closely monitor both the machine path and the animal movements. The high proportion of LCE occurring while working with animals supports this notion of a conceptual weakness in using the quadbike for mustering. When moving mobs of sheep traditionally, the horse would take some of the responsibility for watching where specifically its feet were being placed with regard to holes and obstacles. When working stock with a quadbike however, the rider has to try to monitor and predict not only the terrain in front of the machine but also the movement of all the animals that he or she is in amongst. This divided attention appears to contribute significantly to LCE, with many reports of rollovers simply from dropping a tyre into a shallow rut while turning. Recreational riders on trails in North America, unless riding as part of a group, can choose to watch the track in front and nothing else.

On the basis of this research, the second major weakness in the design from the farmers' point of view is the tendency of the vehicle to roll rather than slide when traction is lost. This makes it too error intolerant for its purpose and produces too high a proportion of LCE where damage is caused to the machine or rider or both. Given that riders are often working in isolation, the loss of their transportation alone can be a cause for concern, but more seriously any entrapment could prove fatal. The newer machines are trending upwards in weight but without any evidence of design considerations to reduce crushing and entrapment, which this study has shown to be the most important target area for interventions.

The crushing injuries to the torso restrict the ability to get out of entrapments unaided, but are being overlooked by those designing injury prevention strategies in New Zealand in favour of the far less frequent head injuries. On the basis of these findings, the current ACC intervention focus is probably not the most cost-effective approach. Further studies are required to estimate the costs of quadbike error intolerance and to develop conceptual level interventions that would result in a vehicle better matched to the actual needs.

The next most common identifiable and discrete task categories are spraying and fencing, both of which form just 6% (n=10) of the total. This indicates the considerable spread of applications of quadbike use on New Zealand farms, and highlights the importance of exercising considerable care in introducing interventions to the sector as whole without broad analysis of potential impact.

The ACC data analysis findings reported in Chapter Three align with this study in many regards, but not in relation to the presence of a towed implement at the time of the event. The ACC data positively identified 3% that had some appliance in tow at the time. This more detailed study found 21% did so. This is probably simply under-reporting due to the limited detail of the event collected on the ACC forms. However, given the scale of the disparity, future epidemiological studies on implement-related quadbike incidents should not rely on ACC data alone to gauge the scale of the problem nor the effectiveness of interventions.

Reversing straight back down a rutted slope is reported by experienced users as sometimes very difficult, but usually impossible. The other LCE scenarios included: failure to allow for the extra width when towing, jacknifing while turning too hard chasing stock and loosing rear wheel traction from the weight of the load shifting at a critical time. The high incidence of LCE where traction was lost reinforces the comments from the farmers regarding the difficulties of judging the inevitable performance drop when towing. The handling characteristics will indeed change very significantly as the quadbike may well weigh less than the trailer and load when feeding out.

Balancing of the load around the trailer axle is critical. If the load sits too far back it will create a lever arm with the trailer axle as the fulcrum produces an upward acting moment at the towbar of the quad. This lifts the rear wheels, which will destabilise any quad hugely when traversing or descending. A two-wheel drive machine would lose all drive.

A most dangerous scenario is clearly created where a large balanced load shifts dramatically while travelling. In several cases these were live loads – dogs (or passengers) who moved back on the trailer to bark at rabbits or get away from the mud thrown up by the quad. Fluid in spray tanks or calf feeders also surges to create the same effect.

5.5.2.4 Task-specific risk factors

5.5.2.4.1 Tasks involving interaction with animals

The taxonomic analysis of tasks involving interaction with animals gives some valuable indications of areas of priority for future research. In particular it is noteworthy that it was in attempting to find or move stock that over a third of the riders in the taxonomy found themselves operating on unsuitable terrain for safe riding. The interactive model incorporating information processing for quadbike LCE developed in this study serves as a very useful analysis device, enabling a variety of factor types from governmental influences to the detection of subtle hazards to be captured and overlaid with data from other LCE. Key findings highlighted by this process include the common failure of farm management to plan adequately for the greatly increased workloads around peak times, and also to purchase machines without critical design weaknesses. At the Active factor level, distraction from the task of riding was a factor in nearly a quarter of all LCE involving animals. Further objective studies are warranted, and eye tracking would certainly be an advantage if present technical lighting difficulties with operating outside a cab can be overcome. In a third of the cases the rider was in control until they attempted to take action to avoid a hazardous situation and then found that the machine would not extricate them. Excess speed was certainly involved in some cases, but other more systemic reasons included inherently poor braking and a lack of traction on hard moist surfaces.

5.5.2.4.2 Spraying

The findings indicate that riders are experiencing LCE through underlying factors including poor matches between spray systems and the quadbikes used, excessive changes in handling and braking characteristics when under load or partial load, and the absence of a safe and systematic approach to the task. These factors interact with negligible training and inadequate alternative personal skills preparation so that risks posed by these error-intolerant systems are also poorly understood.

At an Active Failure level, there is too great a willingness to take risks to finish the job faster, and not simply due to fatigue at the end of a long day. At the information processing stages, the findings suggest that inability to avoid identified and understood hazards is not a problem – which may be due to the lower speeds involved in this task. The surging of fluids unbalancing the machine however, does appear to be a factor in LCE, and reportedly can also reduce the time available for riders to react and throw themselves from the machine to avoid entrapment. Concealed holes and unseen tussocks and lumps instigating tips were especially problematic for these already destabilised vehicles. The additional tanks and hoses on the quadbike can also restrict egress routes and increase entrapment potential.

Objective testing is needed of quadbikes with commercially available spray systems to establish minimum standards of handling performance and stability in either axis. At present there is no control at all on what can be sold, and gross mismatches have been observed; for example placing 100 litres of fluid high on a rack and behind the rear axle makes a backward flip highly likely during ascent.

5.5.2.4.3 ***Fencing***

The quadbike does not appear to be well-suited to this task. Few breaches of farm policy on where, or how, to ride were noted. The predominant underlying factors identified were instead that the machine being used was under-sized and with 'too much being asked of it'. In the majority of cases the rider saw the hazards, knew what to do, and acted upon it, but found the machine incapable of responding adequately. Commonly the riders reported subsequent purchases of six-wheeler and other heavier vehicles following quadbike LCE of this kind.

Further study is needed to provide objective data that can guide safer use of such lightweight vehicles for haulage work, especially on the hard, slick surfaces as encountered during the dryer months in New Zealand. The development of small trailers with independent braking is warranted.

5.5.2.5 Serious injury LCE

Haste, and speed generally, were most strongly linked to serious injury in the analysis of two and three factor combinations. However, at this level of analysis the spread of identified risk factors is very wide and the incidence numbers are very small. Further, specific study is needed with a larger population.

Entrapment of the rider following a quadbike LCE was found in this study to aggravate injuries and delay receipt of medical attention. The importance of prompt attention following serious incidents has been established for survival rates from road traffic crashes (Redelmeier & Tibshirani, 1997), and similar studies are needed for gauging appropriate intervention investment levels in the off-road vehicle sector.

From the detailed findings of the LCE investigations, it is clear that the ROPS fitted acted as injury and damage agents in some LCE and as protective and cost saving devices in others – dependant upon the circumstances. This is broadly in accord with the computer simulation studies conducted by both Honda and the UK Health and Safety Executive. As a result, ROPS cannot be seen as a safety feature with negligible side effects.

A potential source of bias in this line of analysis is that most riders are aware of the campaign by Honda to discourage the use of ROPS. Some farmers reported having removed their ROPS just on the strength of seeing the videos showing computer simulations paid for by Honda that were distributed around New Zealand Young Farmer groups. Those still using ROPS are therefore now sometimes overly-defensive of their decision to continue, and may be inclined to attribute any escape from injury in an LCE to having ROPS fitted.

In the longer term new light vehicle types without the inherent conceptual mismatches of quadbikes are needed for key tasks in the New Zealand agricultural industry. In the meantime, interventions are required to reduce the incidence and severity of LCE.

5.5.3 Interventions

The method produced a substantial body of potential interventions refined iteratively by consultation in the field, and addressing most aspects of the systems. The bulk of these were primary interventions aimed at preventing LCE, as opposed to reducing the severity or speeding recovery times. The process was a strong one and involved many hundreds of hours on site discussing the ideas, in the context of use, with individuals and groups able to critique and refine the ideas of their peers.

The diversity of work systems and cultures encountered at the different sites underlined the importance of participatory methods, not only in the refining of the generic intervention ideas, but also in the implementation. Individuals need to be able to understand how to tailor the interventions from day to day to fit the dynamics of their own context. Donald Campbell, in the foreword to Yin's (1994) text of Case Study Research, speaks of 'the crucial role of pattern and context in achieving knowledge.' Further work is therefore needed on how to assist farms decide what, and how, to change using intervention packages that match their unique contexts.

5.6 Conclusions

The aims of this event-specific study were achieved. Potential interventions were also developed through iterative participative methods.

The investigation method proved effective and robust on site, yielding valuable organisational level/latent factor data through its systems perspective. The interactive causation model generated during the study, and which incorporated information processing features, reflected this approach, and provided a useful analytical and descriptive tool for both risk factors and their countermeasures.

The study generated detailed data on those who had experienced loss of control events and the circumstances including: employment status, demographic variables (gender, age), temporal (time of day, month), ground conditions, terrain, isolation, ancillary implements in use, injury types, characteristics of the more serious injury cases including entrapment, and the presence of roll-over protective structures as protective or injury agents.

From the findings reported in this chapter, it must be concluded that there is evidence of significant mismatches between the actual characteristics of quadbikes sold for farm use in New Zealand and those characteristics that would be desirable based on the typical usage of these vehicles. There are conceptual weaknesses in using a vehicle designed for recreational use on soft surfaces for occupational purposes on all ground conditions - including the towing of heavy loads on hard slick surfaces during high summer.

In the next chapter the key findings from Chapters 1-5 are reviewed, directions for further research identified and final conclusions drawn.