



An Australian Government Initiative



FARM MACHINERY INJURY

Injury Involving Tractor Run-Over

A report for the Rural Industries Research
and Development Corporation

by J. Miller and L. Fragar

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Foreword

Injury on farms and its prevention is a key issue for Australian agriculture and horticulture industries with the common causes of farm injury being well documented.

This in depth report is one of a series investigating preventable risk factors associated with the operation of specific farm machinery.

Death and serious injury caused by tractor run-over on Australian farms has been identified as a major issue for agriculture and horticulture for several decades, and while manufacturers have been slowly incorporating improved designs to reduce this risk, there has been no direct program to reduce such risk.

This report establishes key risk factors and suggests the basis for a multifaceted approach to reducing risk.

The report has been considered by the Farmsafe Australia Farm Machinery Safety Reference Group and action is based on the report findings and the responses from Australian suppliers and operators.

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Executive Summary

Aim

The aim of this project was to collate and analyse available injury data and case reports relating to events involving victims being run over by a tractor in order to:

- Define the injury problem and identify contributing factors. Identify, define and recommend a range of measures to improve safety associated with the operation of agricultural tractors, and to reduce the number and severity of injuries resulting from events leading to the victim being run-over.
- Through the above measures to bring about a reduction in the human and financial costs associated with farm tractor incidents.

Background

Tractor run-over events have long been recognised as a major problem in agricultural areas, and various programs have been devised with a view to reducing the hazards. Design features for tractors, such as neutral start switches and safe operator access have been researched, and to some extent implemented, however injury events continue to occur. The table below indicates the proportion of on-farm tractor deaths reported for the period 1989-1992 that were the result of tractor rollover, run-over and other. Close to 30 percent of the tractor deaths were the result of the victim being run over by the tractor.

Mechanism	Working	Bystander	Total	Percent
Run-over by tractor	17	9	26	29.9
Rollover of tractor	38	10	48	55.2
Other	12	-	12	13.8
Mechanism Not Known	1	-	1	1.1
Total	68	19	87	100.0

Source: Franklin et al, 1989–1992

Method

A search was made of available sources including literature databases, internet, libraries and educational facility library collections for information, case histories, data and research reports relating to events and incidents involving the victim being run over by a tractor.

The data was then collated and analysed to identify factors, whether human, environmental or mechanical, which may have contributed to the various events. Reports and literature from various sources were perused for information of relevance to this project.

The final step was to establish recommendations for improvement in working practices, machine design, machinery standards and education, the aim of these recommendations being to provide a means by which the frequency, severity and traumatic impact of tractor run-over events could be reduced.

Results

An extensive library/internet search revealed a considerable volume of published reports and papers relating to events involving tractor run-over. While in some instances the material was prepared some time ago (eg McDonald, 1972) it is interesting to note that the information contained in these reports was often found to be directly relevant to the current project. This is an indication that although the problem has been widely recognised for some time, and indeed in some cases commendable and practical suggestions for reducing the number and severity of incidents have been put forward, little progress has been made in putting the recommendations into practice.

This may in part be due to the continuing use of tractors that were built before the introduction of safety features which are considered standard for current production machines. Tractors, like other mechanised

systems, are in a constant state of change as new models are produced with improved safety and application features.

Case data was obtained from all Australian states covering a total of 215 incidents, which resulted in the victim being run over by the tractor, pinned by the tractor, or run over by an implement following a fall from a tractor. 110 of the incidents were fatal, and 105 non-fatal. Many of the non-fatal incidents resulted in traumatic injuries to the victim. Data were analysed in accordance with the identified key risk factor areas and is presented in the following section of the report. The fatality data were, in the main, obtained from the individual state work safety authorities, and is considered to be reasonably complete for the period.

Previously published research reports indicated that most incidents occurred to passengers on tractors, a thesis not supported by the data analysed during the conduct of this project, which resulted in identification of incidents involving 46 bystanders, 43 passengers and 107 operators. The role of 19 people playing when involved in a tractor accident was unknown.

Key types of incidents resulting in serious injury have been defined as:

- Fall from tractor and run over
- Mounting/dismounting a moving tractor
- Starting a tractor from the ground
- Run over by a 'parked'
- Pedestrians run over

Risk factors were identified from the available data and reported in relation to operator risk factors, risk factors relating to the machine and environmental risk factors. Consideration of these and of the nature of the injury and the body part affected allowed for options for risk reduction based on the 'Hierarchy of Control' to be documented.

Recommendations

The following 28 recommendations have been developed in accordance with the objectives of this project. Their intention is to provide guidance to tractor designers, manufacturers, suppliers and end users, farm families, regulatory bodies and agricultural advisors, on planning and implementing programs designed to reduce the risk factors associated with tractor operation, and thereby to bring about a reduction in the frequency and severity of traumatic injury caused by tractor run-over.

1. Design/manufacture

- Tractor manufacturers should be encouraged to incorporate into tractor designs, systems to reduce risk of tractor run-over. Feedback on all aspects of the operation of their products, including safety hazards that become apparent in field operation, should be encouraged.
- Tractor designers and manufacturers should be encouraged to provide safe access on all new tractors, allowing access only from outside the wheel track, and preventing access to the electric starter motor while standing between the wheels.
- Manufacturers should be required to fit an interlock control system on all new tractors preventing egress until the controls are locked in a safe position.
- All new tractors should be fitted with an audible reverse warning device.
- Cabin door latch handles should be operated by lifting upwards, or otherwise designed to minimise inadvertent opening.
- An emergency stop control should be fitted in a position accessible from outside the wheel track area of the tractor.
- Tractor designers should continue to improve operator visibility.
- Manufacturers should address the run-over risk in Operators Manuals, and provide practical advice to reduce operator risk.

2. Suppliers

- Suppliers of tractors should ensure that safety information is provided to buyers

3. Existing tractors

- A cost rebate scheme should be instituted for farmers fitting safe access systems to older model tractors.
- All tractors should be retrofitted with ROPs and seat belts.
- Farmers should be advised to fit a guard to older model tractors to prevent 'jump starting'.
- Tractors operating in restricted areas should be required to be fitted with an audible reverse warning device.
- Farmers operating in restricted areas such as packing sheds should be encouraged to investigate the use of tractor/worker detection systems.

4. Guidance material

- The current Australian Centre for Agricultural Health and Safety Guidance Note No 2: Tractor run-overs, should be reviewed and revised to provide practical guidelines for reducing risk of run-overs on farms. Information should include practical guidelines for retrofitment of tractors and for safe work practice.

5. Education and training

- Current tractor safety training competencies and resource material should be reviewed and updated to ensure that protection from tractor run-over risk is addressed effectively.

6. Standards

- The relevant standards should be reviewed to ensure that the content is not ambiguous, effectively reduces run-over risk and is relevant to current technology.

7. Regulation

- New model tractors should be inspected to ensure compliance with plant regulations in all states of Australia.
- Tractor operators licence system should be considered for development and implementation similar to the requirements for plant operators.

8. Promotion

- A media campaign should be carried out to publicise the benefits of fitting a safe access system to tractors.
- A media campaign should be devised to focus farm workers on tractor run-over hazards, demonstrating the economic cost of tractor injury events, and the advantages of safety features. This campaign should emphasise the high risk of tractor run-over injury to young children.
- Farm safety education programs, such as 'Managing Farm Safety', should continue to be developed and made available to agricultural workers.
- Hobby/part-time farmers should be a priority target for education programs.

9. Research

- A research program should be carried out with the aim of developing a practical operator sensing system for use on agricultural tractors.
- A research program should be developed to investigate the advantages and disadvantages of active suspension for agricultural tractors.
- The use of front and saddle mounted chemical tanks should be investigated with a view to determining the hazards presented by such equipment, and to recommend design requirements or alternative designs.
- An in-depth study of tractor accidents similar to that carried out by McDonald (1972) should be carried out with a view to determining hazards present in current production tractor models..
- The farming community should develop an incident reporting system to ensure that reliable data is available for future research projects.

1. Aim

The aim of this project was to collate and analyse available injury data and case reports relating to events involving victims being run over by a tractor in order to:

- Define the injury problem and identify contributing factors.
- Identify, define and recommend a range of measures to improve safety associated with the operation of agricultural tractors, and to reduce the number and severity of injuries resulting from events leading to the victim being run-over.
- Through the above measures to bring about a reduction in the human and financial costs associated with farm tractor incidents.

2. Background

Safety professionals have for many years recognised the high level of injury events in the rural industries, however progress in achieving a reduction in farm injuries is slow.

The very nature of farming, where a large percentage of enterprises are family operated, increases the risk factor. Children live on the farm, exposed to the hazards of a mechanised worksite. Many older farmers continue with active participation in the day-to-day running of the farm. These two groups, the very young and the elderly, are particularly vulnerable to injury. The young have limited ability to recognise danger, while the elderly have reduced agility to escape from a hazardous situation.

Each year in Australia, on average, 36 deaths occur as a result of farm machinery incidents, and more than 500 persons are admitted to hospital following severe injury.

The magnitude of the farm injury incident problem imposes a huge cost on the rural population, in both monetary and personal terms.

Fragar (1996) reported that farm injury costs \$A200–300 million annually in Australia, which is 13–20% of the net value of farm production. Eight factors acting as constraints to the adoption of farm safety measures were identified in the report:

- Farmers values and attitudes
- Economic and cost-related issues
- Shortcomings in education and training
- Age and poor design of farm machinery and safety equipment
- Characteristics of workforce, work practices and farm environment
- Deficiencies in the performance of government departments and other responsible authorities
- Inconsistent support from farmer organisations and rural industry groups
- Competing priorities

Farmsafe Australia established the National Farm Machinery Safety Reference Group with the purpose of developing and implementing strategies to reduce the number of deaths and injuries attributable to on-farm machinery incidents. The National Farm Machinery Safety Strategy was adopted in June 1998, following its development by a Reference Group comprising representatives from rural industry, workers, OHS specialists, agricultural engineers and the farm machinery industry. This document identified farm machinery operators as being the number one occupational group at risk of a work related fatality. Major problem areas were identified as being:

- Tractor run-overs
- Grain auger injuries
- Posthole digger incidents
- Other (including PTO) incidents.

Stakeholders involved in tractor run-over incidents were identified as being:

- Users
- Young parents of children on farms
- Tractor/machinery group
- Rehabilitation sector
- Rescue organisations
- Ambulance
- Regulatory authorities
- Farming women
- Young person – potential farmer
- Agricultural college lecturers
- Engineers

There is some basis for adding the insurance industry to the list of stakeholders.

Available data for 1982-1984 recorded 60 deaths, and 1989-1992 recorded 85 deaths attributable to tractors. The cost to the industry, and to Australia, is not readily ascertained, but is obviously high in both monetary and human values. Fragar et al, (1999), quoted tractor deaths as provided by the states work health authorities.

Table 2.1. Tractor Deaths reported by state OHS authorities from 1995 to 1998.

YEAR	QLD	NSW	VIC	TAS	SA
1985	11	na	3	1	Na
1986	9	na	12	1	Na
1987	10	2	7	2	Na
1988	3	8	9	1	3
1989	11	1	4	0	3
1990	5	4	9	2	0
1991	7	11	7	2	1
1992	8	7	6	2	1
1993	9	5	7	1	1
1994	7	5	8	0	2*
1995	4	2	8	0	
1996	9	3	5	0	2*
1997	7	4	4	0	2
1998	10	5	4	0	1

* = incomplete data

Source: Fragar et al, 1999

Table 2.2 indicates the proportion of tractor deaths reported for the period 1989-1992 that were the result of tractor rollover, run-over and other. Close to 30 percent of the tractor deaths were the result of the victim being run over by the tractor.

Mechanism	Working	Bystander	Total	Percent
Run-over by tractor	17	9	26	29.9
Rollover of tractor	38	10	48	55.2
Other	12	-	12	13.8
Mechanism Not Known	1	-	1	1.1
Total	68	19	87	100.0

Source: Franklin et al, 1989 - 1992

Tractor run-over events have long been recognised as a major problem in agricultural areas, and various programs have been devised with a view to reducing the hazards. Design features for tractors, such as neutral start switches and safe operator access have been researched, and to some extent implemented, however injury events continue to occur.

Published research data indicates that the most common run-over event scenario involves the carrying of passengers on the tractor. The increased fitting of enclosed cabins on tractors in recent years has to some extent reduced this, although incidents continue to occur where passengers, especially children, fall from enclosed cabins. The successful implementation of safety features on tractors is constrained by the practice of retaining at least one older model tractor on the farm for 'odd jobs', these being the very jobs which frequently have the greatest risk of leading to an injury event.

Overseas, attempts have been made to reduce the incident of tractor run-over deaths, especially those involving children. The Republic of Ireland has introduced a 'Code of Practice on Preventing Accidents to Children and Young Persons in Agriculture'. This code clearly states that children under the age of 14 should not be allowed to drive or operate tractors or self-propelled machines, and young persons above the age of 14 should only be allowed to drive under strict guidelines. In the United States of America child labour laws define tasks that are not suitable for children less than 16 years, and impose severe penalties for breaches of the law. Such tasks include operating a tractor larger than 20 horsepower, and riding on a tractor as passenger. It appears to be a strange twist of logic that then allows exemption from this law for immediate family members of the farmer.

While there is general recognition by safety authorities in Australia that there is urgent need for action to reduce the rate of death and injury associated with run over by tractors, there is clearly a need for a more strategic approach to be developed to achieve this goal.

3. Method

This report is the result of a research project carried out by the Australian Centre for Agricultural Health and Safety with a view to implementing the recommendations of the National Farm Machinery Safety Strategy. Research was carried out under the guidance of the National Farm Machinery Reference Group.

A search was made of available sources including literature databases, internet, libraries and educational facility library collections for information, case histories, data and research reports relating to events and incidents involving the victim being run over by a tractor. The data was then collated and analysed to identify factors, whether human, environmental or mechanical, which may have contributed to the various events. Reports and literature from various sources were perused for information of relevance to this project.

The final step was to establish recommendations for improvement in working practices, machine design, machinery standards and education, the aim of these recommendations being to provide a means by which the frequency, severity and traumatic impact of tractor run-over events could be reduced.

For the purpose of this project the definition of 'tractor' has been those machines generally thought of as agricultural tractors, and used as a source of motive power in agricultural type operations. The definition generally refers to wheeled type machines, however in this report reference may be made to tracked machines, on the understanding that these are frequently used for similar purposes in agricultural operations to wheeled types. Specialised machines such as excavators, backhoes, etc have been excluded. The increasing use of machines such as front-end loaders, skidsteer loaders, backhoes and excavators on Australian farms suggests there may be a need to carry out a project devoted to these machine types at a later date.

The definition of 'tractor run-over' has been taken to include those incidents where the victim was run over by an attached implement, provided the tractor was involved in the lead-up to the event (eg the victim fell from the tractor and was run over by the trailed implement), on the understanding that the incident was caused or contributed to by some deficiency in the design or operation of the tractor, or by some environmental factor affecting the operation of the tractor. On the same grounds, incidents where the victim was pinned between the tractor and another object have been included, the rationale being that if the prime cause is the same, it is of little significance whether the victim was run over or pinned.

A small number of incidents, involving an agricultural tractor, occurred away from an agricultural enterprise, eg mowing a sports oval. These incidents were included in the data analysed, on the basis that deficiencies in tractor design or operation associated with the event would be the same as for an agricultural event.

The term 'accident' has been deliberately avoided as much as is possible in this report. It is commonly understood to mean 'an event which is unavoidable'. The common patterns into which all the events investigated could be placed would appear to negate any possibility of 'luck' being a factor. It is considered that all of the events investigated could have been avoided; therefore the word 'accident' is not used except in direct quotations. Luck becomes a factor only in the outcome of the incident, whether the victim is killed, injured or avoids injury altogether. The people who work on the land must realise that every time a person approaches a tractor, whether as operator or bystander, a number of factors may be triggered. Potential for a serious incident depends upon the combination of these factors.

This project was not carried out with the purpose of apportioning blame for the cause of tractor run-over injury events. While it could be said that human error is behind each incident, in each case there were a number of factors, and error, or lack of foresight, which may have been attributable to the operator, the farm management, the supplier of the machine, the manufacturer and the designer. Such 'finger pointing' would not have been fruitful, and indeed could well be detrimental to the cause of improved farm safety. The purpose of this work has been to identify factors involved in tractor injury, and to put forward recommendations focused on reducing the number and traumatic impact of tractor run-over injury events.

4. Literature Search

An extensive library/internet search revealed a considerable number of published reports and papers relating to events involving tractor run-over. While in some instances the material was prepared some time ago (eg McDonald, 1972) it is interesting to note that the information contained in these reports was often found to be directly relevant to the current project. This is an indication that although the problem has been widely recognised for some time, and indeed in some cases commendable and practical suggestions for reducing the number and severity of incidents have been put forward, little progress has been made in putting the recommendations into practice. This may in part be due to the continuing use of tractors that were built before the introduction of safety features which are considered standard for current production machines. Tractors, like other mechanised systems, are in a constant state of change as new models are produced with improved safety and application features.

The internet search revealed the existence of a vast array of extension service fact sheets relating to tractor safety, of varying degrees of professional presentation. The very fact that this current project is considered necessary is a clear indication that methods used to date to introduce a satisfactory level of tractor safety into the rural scene have not proved to be effective, and that there is a need for a new approach to be developed which may, at least partially, overcome inherent impediments to change.

McDonald (1972), in what appears to be the most in-depth study to date, investigated 520 tractor incidents. One hundred and twenty-two of these incidents can be classified as run over or pinned by the machine or associated equipment, as defined for the purposes of this project. Sixty-seven of these incidents involved the operator or passenger being thrown off, or falling off, the tractor. McDonald divided the run-over incidents into a number of incident types:

- Adult mounting
- Adult dismounting
- Adult falling/thrown off
- Adult standing or running beside
- Children mounting
- Children dismounting
- Children standing beside

Each of these incident types was further broken down into categories depending on the factors causing the incident. The report included a large number of recommendations for modifications to tractor design to reduce the occurrence of similar events in the future. A number of these recommendations have subsequently been adopted in tractor design, either because of legislative requirements or owing to normal advances in tractor technology incorporating the recommended change. Some recommendations have been made redundant by technology advances, eg a number of recommendations regarding tractor brake systems have been made unnecessary by the practice of fitting disc brakes to the majority of modern tractors. Other of the recommendations, although appearing to have a reasonable chance of contributing to a noticeable reduction in injury and death while being economically feasible, have not been applied to a wide range of tractor designs.

Some recommendations put forward by McDonald which have not become generally included as a feature of tractor design, and which on face value appear to be feasible, are:

- Provide a parking brake system that cannot be released by three and four year old children.
- Provide access so that the driver steps on and off the tractor outboard of the wheel track.
- Adjustable mounting platform to cope with all wheel settings.
- Prevent operation of the starter motor from between the front and rear wheels.
- Provide an engine starter operating mechanism that cannot be inadvertently operated by children.

The Work-Related Fatalities Study Team (WRFST) (2000) found that the farming industry fatality rates for incidents involving tractors was 5.52 per 100 000 workers in the 1989 to 1992 study, compared to 7.90 per 100 000 for the 1982 to 1984 study. This apparent downward trend could reasonably be attributed to the increasing use of ROPS and enclosed cabins on tractors. This supposition is supported by a decreasing proportion of rollover incidents compared to run-over incidents in the second study.

There were 144 tractor related fatalities studied, of which 52 (36%) resulted from a pedestrian being hit or someone falling or getting off a tractor and subsequently being hit by the tractor or attached machinery. These included:

Incident type	Number
Fell from the tractor and run over by the tractor or	22
Mounting a moving tractor – 5	5
Starting a tractor from the ground – 6	6
Run over by a ‘parked’ tractor – 12	12
Pedestrians run over – 7.	7

This study found that of 144 fatalities investigated, only 23 (16%) of victims were eligible for a workers’ compensation payout, inferring that the remainder were either self-employed farmers or children not eligible for compensation under the compulsory compensation system for employees.

Fifteen of the run-over victims were below the age of fifteen. Nine fell from the tractor and were run over, nine run over while standing or playing near the tractor, and one by a tractor thought to be parked. The report identified the main contributing factor, apart from the young age of the victim, as “lack of adequate supervision, where children were allowed to ride on, or be too near, working machinery. In none of the incidents where a child was killed while riding as a passenger was proper seating with seatbelts fitted to the tractor.”

Thirteen of the victims were aged over 65 years. Thus 28 (15 children, 13 elderly) of the tractor run-over fatality victims (54%) were outside the generally accepted working age range of the civilian workforce.

The WRFST report included recommendations from coroners and OHS authorities, many of which have relevance to this current project. The team commented:

“Apart from the absence of safety equipment and the effects of the terrain, the main contributing factors to the tractor-related deaths involved work practices, work procedures and work organisation. Such information is of use in directing efforts in the education and training of tractor users, manufacturers and distributors. Listed below are some of the contributing factors and associated comments concerning work practices, procedures and organisation that occurred in 101 separate fatal incidents, and that were identified by the coroners and/or OHS authorities.”

- Allowing children near work sites – a number of children were killed when they accompanied their relatives on tractors while they were working. There were also five children run over while they were on the ground near working machinery. It was unclear in most cases as to the parts played by economic and family pressures in these deaths. The alternatives of leaving children completely unsupervised away from danger, or of not getting necessary work done, may not be reasonable. Despite this, coroners and OHS authorities in the current study repeatedly recommended that children should not be allowed to ride on tractors and machinery, or to be allowed near any working machinery while on the ground.

- Carrying people on tractors and machinery not equipped with adequate seating and seatbelts – falls from tractors were characterised by lack of seating for passengers, and lack of seatbelts where seats were available.
- Starting a tractor while standing next to it on the ground – attempts have been made by engineers to render this impossible but, in the current study, there were three incidents where safety mechanisms were deliberately bypassed in order to get the tractor started, resulting in the person being run over.
- Leaving the motor running while doing maintenance on, or handling attachments to, a tractor.
- Operators using tractors knowing that some of their equipment was faulty.

Ferguson (1999) analyzed deaths on Queensland farms from 1990 to 1998 and found that the total number of tractor related deaths had increased over the period. Rollover fatalities had decreased from 5.6 to 3.9 per 100 000 workers, however run-over deaths increased from 1.7 to 4.4 per 100 000 workers. Like many researchers, Ferguson found a high incidence of run-over deaths in children below 10 years old and farmers over 64 years.

His recommendations were to:

- Fit Rollover Protective Structures to all tractors
- Encourage fitting of safe-access platforms to older tractors
- Discourage practices of starting tractors from the ground, carrying passengers on tractors
- Prevent young children from entering work areas where tractors or other machinery are operating.
-

Ferguson (2000) found that the average age of tractors in Queensland was 18.1 years, with tractor age in sheep operations being the greatest at 25.1 years. This survey indicated that 28.9% of tractors in Queensland were fitted with enclosed cabins, and 18.5% had enclosed cabins and seat belts. 24.2% were fitted with ROPs (including enclosed cabins with ROPs structure).

Fragar and Franklin (2000) quoted the Statement on Tractor Run-over Deaths, from the 1991 National Tractor Safety Conference. The statement addressed the problem of tractor run-overs and access, as follows:

Tractor run-overs and access

Statement of Problem

A significant number of people are injured or killed by being driven over or crushed by a tractor while alighting, mounting or working with it.

The problem is/has been caused by:

- Crushing when the operator attaches implements
- People being thrown from moving tractors
- Tractors moving when the operator opens gates, etc
- People slipping as they mount or alight
- People running beside the tractor to regain control
- Standing alongside the tractor, for instance when jump starting
- Passengers

Other contributing factors are:

- Age of farmer: there is mounting evidence that older (and even experienced) farmers lose co-ordination skills with age
- Age of machines: the majority of accidents occur on older machines
- Condition of machinery: there is a direct correlation between tractor accidents and the amount of maintenance afforded the machine
- Fatigue
- Climatic conditions

We recommend the following actions:

- Modification of early model machinery to current safety standards by industry manufacturers
- National support and funding be given to local Farm Safety Action Groups for safety programs to be directed to farm families

Ashby and Day (1995) made the following recommendations for tractor design relevant to tractor run-over prevention, on the grounds that incorporation of such features would greatly reduce reliance on operator behaviour for safe tractor use:

- The provision of passenger facilities including seat, seat belt and protection by ROPs
- A dead man seat brake that operates when seat is vacated, commonly used in other industrial equipment such as forklifts
- An ignition switch which starts only when tractor is in neutral
- Improved seat design
- Safe access platforms with hand holds to prevent falling under the rear wheels while mounting and dismounting
- Reversing 'beepers' to alert bystanders to a reversing tractor
- Children should not ride on tractors
- Farming activities in which children are involved should be appropriate to their age and have constant adult supervision
- Designated, preferably fenced, children's play areas should be provided around the home and in key locations on the farm.
- Children should not be permitted to play in farm work areas
- Integration of the range of existing materials on safe tractor operation into one document, widely distributed
- Training in safe tractor operation and maintenance
- Hobby farmers as well as professional farmers to be included in tractor safety campaigns
- Development of a licence system for tractor operation

Among others, **Bean** (1991) put forward the theory that on family farms older tractors are often reserved for general duty, with more modern machinery put to work on higher production tasks. The older tractor is thus utilised on what are often the more hazardous tasks, has less safety equipment, and is more likely to be operated by inexperienced operators, the very young or the elderly.

Lough et al, (2001) placed tractor run-over fatalities as top priority for prevention measures, based on incident numbers and trends. The adult work related deaths for Victoria from 1990 to 2000 showed an increase in tractor run-over deaths in recent years, with a reduction in rollover incidents.

The Canadian Farm Safety Association (Farmsafe, Volume 26, No 2) rated tractor run-overs as accounting for one in four of all agricultural deaths, and one in eight hospitalisations. The theme for the 2001 Canadian Agricultural Safety Week was 'Run-overs are preventable', indicating the seriousness with which the Canadian association regards run-over incidents.

The Canadian Agricultural Safety Program (CAISP) released a comprehensive report on farm fatalities in 2001, covering the years 1991 to 1995. A total of 901 farm deaths were identified, of which 140 (15.5 %) were tractor run-over incidents. These victims age groups were 57 aged 0-14, 34 aged 15-59 and 49 aged 60+. Jump-starting accounted for 2.2% of all fatalities, with older adults making up 70% of jump-start fatalities.

A similar report was released for hospitalised farm injuries for the period April 1990 to March 1995. This report showed 222 victims pinned or struck by the tractor, 197 run over, and 101 fell from the tractor and then run over. In all, 31% of machinery injuries were caused by being struck, pinned or run over by machinery.

A farm tractor was involved in 27.9% of hospitalised injuries, and 46% of fatalities.

CAISP released another report, Farm Run-over Injuries in Canada 1990-1994, in 2001. This report showed a ratio of hospitalised to fatal farm run-overs for tractors of 5:1. The information contained in the Canadian report was a valuable reference during the progress of the tractor run-over project. Six recommendations were put forward by the authors:

1. 20.8% of all run-overs are to children less than 10 years of age. Strategies must be put in place to remove this type of exposure to potential run-over hazards.
2. Investigation into engineering options that would result in unmanned machinery being immobilized (eg dead man switch on tractor seat).
3. Based on anatomical injury patterns, injuries are often ones that inhibit victims from accessing help alone. Consequently, the use of communication technology should be investigated for more rapid reporting of injury events.
4. The risks involved in farming have been identified: as part of prevention efforts, there is an important need to get this information into the hands of farmers, farming organizations and equipment manufacturers. CAISP will work with the Coalition in order to do this.

5. There are specific patterns of run-overs for targeting of prevention activities:
 - Run-over by unmanned tractors running down hill: ensuring proper brake maintenance and proper parking practices would contribute to diminishing these incidents;
 - Jumpstarting tractors: this is a significant pattern in run-over injury. Tractors require regular and proper maintenance so that farmers do not have to resort to this. Another preventive measure may be to place warning signs on ignition boxes to discourage this practice;
 - Tree branch knock-offs: upgrade of protective devices such as protective cages and deadman switches would be important.
6. Environmental changes also need to be made. In particular, farmers should make sure that roadways are safe.

The authors identified 4 clear patterns of run-over injuries:

- Rider run-overs – 47 fatalities, 179 hospitalisations
- Blind run-overs – 21 fatalities, 82 hospitalisations
- Unmanned run-overs – 16 fatalities, 79 hospitalisations
- Jumpstart run-overs – 8 fatalities, 22 hospitalisations.
-

The report also found that the mean length of stay in hospital for non-fatal injuries was ten days, a significant figure when considering the cost of farm tractor run-over incidents.

CAISP, in the executive summary to the Farm Run-over Injuries report said:

“The concept of farm injury surveillance which guides CAISP is much more than simply the collection of data. CAISP wants to use the information to develop a clear understanding of what causes these tragic injuries. CAISP data show that there are recurrent patterns of injury across the country. These are **not** random or isolated ‘incidents’.”

Murphy et al, (1996) emphasised the difficulty in classifying unintentional agricultural fatalities. ‘Agricultural’, ‘rural’ and ‘farm’ are terms that are often used in the same context. Also, the location of residences on agricultural worksites creates a difficulty in distinguishing between work and non-work injuries. In relation to tractor run-over incidents the report found that: “Youth aged 14 and under were run over while being a rider in six of 14 cases (42.9%) or whilst being a bystander or on-the-ground helper in eight cases (57.1%). Senior farmers, on the other hand, almost always were run over while working with or around the tractor as the operator, a scenario that occurred in 14 of 16 cases, or 87.6% of the run-over cases for their age group.”

Crabb (2000) found that functional design dominates the design environment but that functional design does not include the needs of the user. The report stated that:

“Human factors are considered where a specific legislation requires action. For example, to exclude access to drive units, pulleys, belts, shafts. Most often these are addressed at the final stages of production usually by adding guards. This highlights the fact that little, if any, regard is given at the inception of the design process to producing inherently safer designs that recognise human factors, the risks that can arise from miss-directed motivation or the strengths and weaknesses of human adaptability.

The reason for this lack of inclusion of human factors in design in order to produce inherently safer designs resides in three factors:

- Low levels of awareness of human factors amongst agricultural engineering designers
- Poor understanding in the marketplace of the value of designing for users as well as function
- That the implementation of health and safety is almost wholly reactive through legislation.

Notwithstanding the existing situation, there was encouraging evidence that agricultural engineering designers would welcome measures to improve their knowledge and access to information on human factors, risk, accidents and the reasons why these occurred, legislation, both existing and proposed.”

It was interesting to note that none of the engineering designers who took part in the above project had received formal training in risk assessment. This seems to be a matter requiring immediate action given that the designer has a responsibility to carry out a risk assessment on the product, and to design a product that is safe to operate. The author also found that the lack of reference by designers to standards, legislation, etc was ‘abysmal’. There would appear to be a case for research into the level of use of applicable standards by Australian designers. The results found by Crabb indicate a need for a strict assessment of machinery imported from overseas to ensure that required standards are actually designed into the machine.

Crabb also found that because customers were not interested in safety features the designers had no incentive to include them in the design. Many designers were concerned that the customer would not pay more for an inherently safer machine.

Rechnitzer (2001) said that:

“Injury represents a failure in some part of the work system. A system consists of people interacting (working) with the environment. It is self evident that injury can not occur unless people are present, hence the often quoted – and largely misunderstood and misrepresented fact – that human error is the causal factor in 90% of accidents, implying that if people were ‘more careful’ then we would have many fewer accidents!”

“The scientific approach to accident prevention recognises that there is usually a multi-factored chain of events leading to the ‘accident’. Although one of the factors must at least involve humans, effective injury prevention strategies (Haddon’s Matrix), address all three major factors in the injury chain – the host (person), the energy source (machine, load etc) and the environment.

It also recognises that humans can not perform ‘correctly’ 100% of the time, and thus the need to properly consider ‘passive’ strategies in which the system design is changed to protect automatically the population at risk, without each vulnerable individual having to take action.”

“Good safety design requires firstly, and fundamentally, an understanding of the performance requirements for the particular system. Although this may appear self-evident, good performance specifications take some effort, and it is at this point that we see that safety risks will be either built-in or largely eliminated.”

Toft, when discussing the need for engineers to know aspects of ergonomics said:

“Considerations such as cognitive compatibility and usability of equipment and system design are becoming issues of increasing importance, as society becomes more reliant on information technology and automation. That engineers contribute to human error in these systems through latent design error and poor management decision making is well documented. Therefore, the role of engineers can be considered integral to positive outcomes in workplace safety.

Wheatstone (1993) found that in New Zealand safety to most farmers meant using common sense and being aware of hazards.

Overall, the responses indicated that farmers saw safety as a cost, without compensating benefit. Because they did not see safety as a problem, farmers perceived external measures to be bureaucratic and unnecessary impositions. There is therefore a need to educate farmers about the true costs of accidents and illness to themselves and their industry. A strong link needs to be made between safe operation and continuing farm business viability. If farmers can be convinced there is a return on safety and training, they may be more willing to make the investment.

Farmers perceived time, effort and cost as barriers to the adoption of safer practices.

5. Research Results

5.1 Australian data

Case data was obtained from all Australian states covering a total of 215 incidents, which resulted in the victim being run over by the tractor, pinned by the tractor, or run over by an implement following a fall from a tractor. 110 of the incidents were fatal, and 105 non-fatal. Many of the non-fatal incidents resulted in traumatic injuries to the victim. Data was analysed in accordance with the identified key risk factor areas and is presented in the following section of the report. The fatality data was in the main obtained from the individual state work safety authorities, and is considered to be reasonably complete for the period.

The Work-Related Fatalities Study Team (2000) found an average of 11.8 fatalities per year resulting from tractor run-over injury incidents for the period 1989-1992. Fatality data from state workplace safety authorities is derived from fatalities investigated by state work health authorities. The current study identified an average of eight fatalities per year for the period 1998 to 2001. It was interesting to note an apparent reduction in the average number of victims falling from the tractor and being run over, again raising the possibility that use of enclosed cabins and ROPs has assisted in reducing the incidence of tractor run-over injury events. However, as the work health authorities have depended on referral of deaths cases from police and coroners, the fatalities data for this later period may be incomplete.

Table 5.1: Comparison of fatalities from tractor run-over. (Average number per year).

Event type	1989-1992	1998-2001
Fall and run over	4.6	2.4
Mount/dismount	1.3	0.6
Jump start	1.3	1.8
Parked	2.8	2.4
Pedestrian	1.8	0.8

The data above shows a noticeable decrease in the number of events resulting from the victim falling from the tractor. Jump-starting is the only type of incident to show an increase. The low numbers involved in each incident type prevents any firm conclusions from being drawn from this data.

Location of data relating to non-fatal cases, in the absence of a central reporting system, is extremely difficult and time consuming, and it is recognised that the data located during the project is by no means complete. Non-fatal injury incidents were identified from a number of, with most input from the state occupational health and safety authorities, and the hospital admissions survey database.

The case data available has provided a basis for observation of trends and patterns in tractor run-over injury occurrences. Absolute statements regarding the relative importance of all factors involved in tractor run-over accidents are not possible given the acknowledged deficiencies in data, however it is considered that reasonable assumptions may be made based on the evidence available, on the understanding that the data, while in the case of non-fatal injuries not complete, is representative.

Overall, incidents were identified that occurred during an 18 year period from 1984 to 2001.

Previously published research reports indicated that most incidents occurred to passengers on tractors, a thesis not supported by data analysed during the conduct of this project, which resulted in identification of incidents involving 46 bystanders, 43 passengers and 107 operators, with 19 unknown.

McDonald (1972) found 59% of incidents involved the operator or passenger being thrown or falling off the machine, whereas this project identified 25% in this category. This may be an indication of the

benefits arising from the increase in use of ROPs and enclosed cabins in recent years. The practice of fitting ROPs to tractors may well be the most significant advance seen in rural safety in recent years.

During the course of the data search, and from reference to previous injury investigations, the need became apparent for an accident reporting system designed to make readily available to researchers the specific information necessary for reliable analysis of hazard factors involved in injury and fatality events in rural industries. Hospital admission data is difficult to obtain and interpret, and there is no means available for obtaining statistics on victims visiting a medical practitioner but not admitted to hospital.

5.2 Overseas data

A search of internet sources was carried out to ascertain the level of incidents overseas, and to obtain details of research that may have been carried out by overseas institutions. The following tables present data from the United States of America, Canada and the United Kingdom.

Table 5.2 can only be considered as being representative of American data, as full reports are not available from some states. Information is based on data obtained from various internet sources. The National Safety Council reported in the 1999 edition of 'Injury Facts' that during 1997 66 persons died in the United States of America from tractor run-over injuries, a rate of 1.7 deaths per 100 000 tractors.

Table 5.2: Age range of victims of tractor run-over incidents in USA. Years 1986 to 2000

Age group	Fatal			Non-fatal			Total		
	Male	Female	All	Male	Female	All	Male	Female	All
0-9	13	6	19	1	1	2	14	7	21
10-19	9	1	10	3	1	4	12	2	14
20-29	3	2	5	5	0	5	8	2	10
30-39	12	1	13	4	1	5	16	2	18
40-49	15	1	16	5	0	5	20	1	21
50-59	16	1	17	6	1	7	22	2	24
60-69	27	1	28	5	0	5	32	1	33
70-79	28	1	29	1	0	1	29	1	30
80-89	8	2	10	2	0	2	10	2	12
All	131	16	147	32	4	36	163	20	183

The Canadian Agricultural Safety Week Bulletin number 5 stated that each year in Canada fifteen people are killed and eighty hospitalised as a result of being run over by a tractor.

Table 5.3: Age range of victims of tractor run-over incidents in Canada. Years 1990 to 1999

Age group	Fatal			Non-fatal			Total		
	Male	Female	All	Male	Female	All	Male	Female	All
0-9	4	1	5	0	0	0	4	1	5
10-19	2	0	2	1	0	1	3	0	3
20-29	1	1	2	1	0	1	2	1	3
30-39	2	0	2	0	1	1	2	1	3
40-49	2	0	2	0	0	0	2	0	2
50-59	1	0	1	0	1	1	1	1	2
60-69	6	0	6	1	0	1	7	0	7
70-79	4	1	5	0	0	0	4	1	5
All	22	3	25	3	2	5	25	5	30

Table 5.4 is based on information obtained from the HSE website of the United Kingdom.

Table 5.4: Age range of tractor run-over victims in the United Kingdom Years 1990 to 2001.

Age group	Total
0-9	3
10-19	0
20-29	0
30-39	0
40-49	1
50-59	4
60-69	1
70-79	7
Unknown	1

5.3 Characterisation of run-over events

The following types of events were identified:

Falls from tractors. Falls from moving tractors occur to both operators and passengers, although passengers are much more prominent in this type of event. Passengers, in the absence of an approved seat and seat restraint, may stand on the step, stand on the drawbar, or sit on the mudguard. Falls may occur through the effects of: environmental factors, such as rocks, stumps, ditches etc causing the machine to lurch suddenly, sudden speed and/or direction changes by the operator, and by passengers slipping from an insecure seated or standing position.



Passengers standing on the operator's platform, or sitting on the mudguard, are at risk of falling in front of the rear wheel and being run over.

Fall injury incidents have also occurred as a result of the operator standing on the tractor platform or step while driving the machine, or by the operator or passenger attempting to mount or dismount the tractor while it is in motion.

Injury reports of some run-over accidents refer to the victim dismounting from a tractor while leaving it moving slowly across a field, with the purpose of carrying out a procedure such as feeding out hay from a trailer, and either being run over while dismounting, or later when attempting to remount.

Falls may be the result of the victim being knocked from the tractor by a tree limb.

Blind run-overs. Blind run-overs occur when the victim approaches or is in the vicinity of the tractor unseen by the operator. The victims are frequently young children who because of their small size may not be seen by the operator. Included in this category for the purpose of this project are cases where workers assisting the tractor operator have been run over while attaching an implement to the tractor or carrying out maintenance on the implement. The victim may be unnoticed by the operator because of an area in the vicinity of the tractor that is not visible from the tractor operator's position due to the tractor design, or from the victim moving into the path of the tractor from behind another object.

Operator on the ground. These events result from the tractor being parked without applying the handbrake, or by failure of the handbrake. This type of event frequently occurs when the operator stops the tractor for a short time to carry out a routine operation such as dismounting to open a farm gate. The tractor may then roll forwards, catching the operator unawares.

Jump-starting. The cause may be the operator attempting to start the tractor by shorting out the starter motor terminals, or standing beside the tractor to operate the start switch. Either of these actions will result in a potential run-over situation should the tractor transmission have a gear selected. One case was identified where the operator was in front of the tractor hand cranking the engine, and the machine started in gear.

Tractors only require jump-starting when there is a fault in the electric starting system, therefore most of the injury incidents that come within this category could be eliminated by correct tractor maintenance.

Statistics show a trend for older operators to have a higher risk of being run over while starting the tractor from the ground. This may be a result of these operators being more likely to use older model tractors or reduced agility on the part of the operator.



Operators are at risk of being run over while starting from the ground by tractors having access to the area between the front and rear wheels

5.4 Cost of injury

The cost of tractor run-over injury to the individual farmer, the agricultural industry and the country is difficult to ascertain with any certainty. The complex nature of the make-up of the cost structure makes calculation difficult, even if the amounts of the various costs could be identified.

Day et al, (1999) estimated cost of rural injury to be 13-20% of net farm income, an estimate that presents a challenge to all those interested in farm safety, and the reduction of monetary and human costs of farm injury.

Workplace Standards Tasmania has quoted figures of workers compensation claims for tractor related injury, for the period 1989 to 2001, at an average of \$8 200.00 per claim. These figures, of course, relate only to the relatively few victims who are eligible for workers compensation. The compensation payment is only the direct cost of the victim's compensation – additional cost is raised by such items as damage to machinery, time lost by other workers attending the victim, cost of emergency rescue operations, time spent by the owner/manager in administrative matters, cost of replacement staff, loss of production from time lost, etc. In addition, the victim, when allowed to return to work, can be expected to achieve a much reduced production level for some period of time. Should the injury prove fatal, the costs are raised to a much greater level.

Fragar et al, (2000) in summarising injury costs, said:

The true estimates of current cost of farm injury are not immediately available. What information is available indicates:

- In addition to medical costs, farm injury results in significant direct farm costs such as damage to plant and equipment and labour costs.
- Costs appear to vary depending on the industry in which injured persons are working at the time of the injury.
- The full costs of farm injury are probably not being borne by the industry.
- Further work to define the costs of farm injury, and the benefits of farm safety programs is required.

There have been no advances since that report was released. There has been little investigation into the cost of injury, except for areas such as the Tasmanian workers compensation costs.

Enabling farmers to understand the true cost of injury to the industry, and to their own individual enterprises, is a major step in bringing about a greater dedication to hazard reduction on the farm. Farmers, and farm workers, will support safety programs provided they can see clear benefits for themselves and for their business.

6. Risk Factors

Data pertaining to all available cases from 1984 to 2001 was analysed to ascertain the factors involved in the events that lead to the victim being injured. The factors were recorded as being human, mechanical or environmental, and patterns of event development became apparent.

6.1 Human risk factors

Age

Table 6.1 shows the age ranges for known tractor run-over fatality cases in Australia for the period 1984 to 2001.

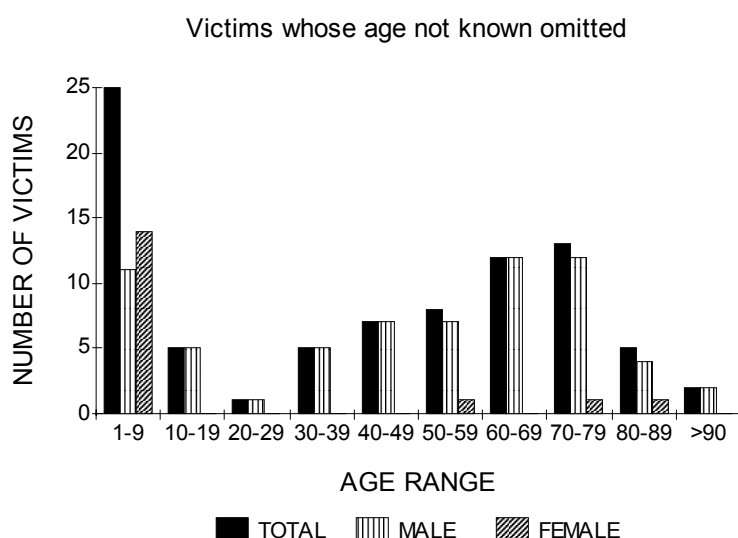
Table 6.1 Age range of victims of fatal tractor run-over incidents 1984–2001.

Age group	Male	Female	Total
0-9	11	14	25
10-19	5	0	5
20-29	1	0	1
30-39	5	0	5
40-49	7	0	7
50-59	7	1	8
60-69	12	0	12
70-79	12	1	13
80-89	4	1	5
>90	2	0	2
Unknown	27	0	27
Total	93	17	110

Source: State Workcover data

The number of the very young and older people found among the victims of tractor run-over fatality events is illustrated in Figure 6.1.

Figure 6.1: Age range of victims of fatal tractor run-over incidents.



Non-fatal injuries

The data available for non-fatal tractor run-over incidents is far from complete. Data given below relates to the case information that could be determined, and is considered to be representative of this form of event.

Table 6.2: Age range of victims of non-fatal tractor run-over incidents.

Age group	Male	Female	Total
0-9	21	6	27
10-19	18	4	22
20-29	7	2	9
30-39	7	3	10
40-49	5	1	6
50-59	8	1	9
60-69	5	1	6
70-79	6	0	6
80-89	2	0	2
>90	0	0	0
Unknown	7	1	8
Total	86	19	105

Figure 6.2 shows that the occurrences of run-over injuries, like fatalities, are far higher for children in comparison to other age groups.



Figure 6.2: Age range of victims of non-fatal tractor run-over incidents.

Run-over events, fatal and non-fatal

Combining the available data relating to all tractor run-over events, both fatal and non-fatal, gives an overview of the problem, although the dearth of information on non-fatal events means that the overview is somewhat understated.

Bearing in mind the incomplete nature of the data, it is still possible to reach conclusions regarding the overall patterns observed, and to formulate procedures aimed at combating the hazards observed.

There is a need for further research into the occurrence of tractor injury events, to ascertain the true picture and provide a basis for further remedial actions to be taken.

Table 6.3: Age range of all victims of tractor run-over incidents in Australia, 1984 to 2001

Age group	Male	Female	Total	Percent
0-9	30	22	52	24
10-19	23	4	27	13
20-29	8	2	10	5
30-39	12	3	15	7
40-49	12	1	13	6
50-59	15	2	17	8
60-69	18	1	19	9
70-79	17	1	18	8
80-89	6	1	7	3
>90	2	0	2	1
Unknown	34	1	35	16
Total	177	38	215	100

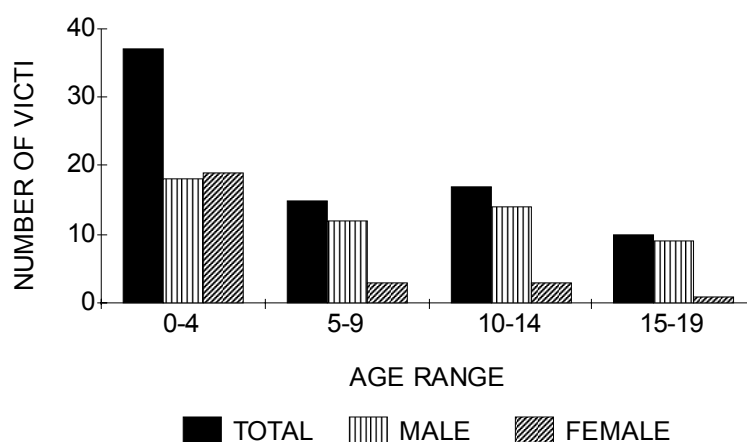
The combined data once again emphasises the high proportion of children among the victims, and reinforces the need for priority to be given to developing and implementing techniques to reduce tractor run-over of children.

The age range of victims of tractor run-over incidents in Australia shows that no age group is free from risk, with the greater number of incidents occurring to very young children. The incidence of injury to young children may be broken down further, as shown in Table 6.4.

Table 6.4: Age distribution of child tractor run-over victims in Australia.

Age group	Male	Female	Total
0-4	18	19	37
5-9	12	3	15
10-14	14	3	17
15-19	9	1	10

Figure 6.3: Age distribution of child tractor run-over victims in Australia.

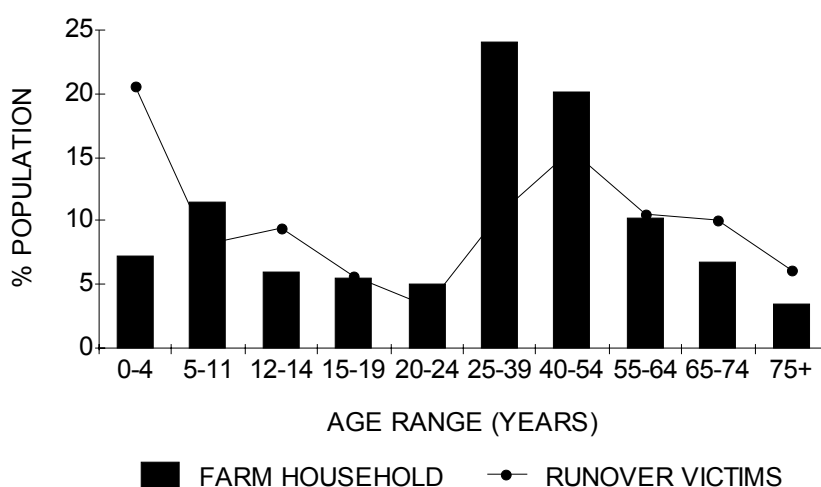


The data in Table 6.4, and shown graphically in Figure 6.3, indicate quite clearly that many of the incidents investigated have involved very young children and babies. Reducing the risk factor to this age group must be a priority for action.

It is interesting to note that while female children are at high risk in the 0-4 year old age group, the number of female victims decreases markedly in older age groups. It may be correct to assume that this phenomenon is a result of older female children turning to more domestic pursuits with their mother, and a tendency on the part of fathers to encourage male children to take an interest in the farm activities. There is, however, no evidence to prove this assumption.

Fig 6.4 shows clearly the disproportionate number of very young children who become victims of tractor run-over events.

Fig 6.4: Comparison of the age range of run-over victims (percent) to the age of persons in farm households (percent)



Source of data for farm households: Fragar & Franklin (1999), Farmsafe Australia Mid-term Review.

Table 6.5 shows that the incidents are equally divided between falling off the tractor and being run over, and blind run-over. This re-enforces the view that the under-five year old group, as the largest both numerically and relative to the number in farm households, must be a priority for action in a safety program.

Table 6.5: Mechanism of child tractor run-over injuries.

Age group	Fall off	Blind	Unknown	Total
0-4	19	18	0	37
5-9	11	4	0	15
10-14	9	5	3	17
Total	39	27	3	69

The below five-year-olds are equally divided between ‘fall off’ and ‘run over’ incidents and ‘blind run-over’ incidents. Older children are more likely to be injured in an incident where they fall off the tractor and are run over.

Table 6.6: Australian tractor run-over incidents Comparison of victims age to age of farm workers – percent of total

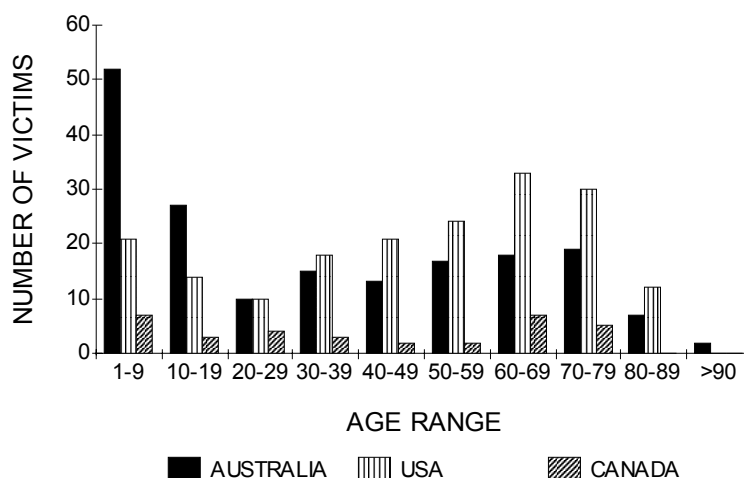
Age range	Farm workers	Run-over victims
15-19	7	10.6
20-29	21	8.9
30-39	21	13.3
40-49	21	11.5
50-59	17	15
>60	13	40.7

The age distribution of male farm owners, managers and labourers in Australia in 1991, as published by Fragar et al, (2000) was used for the comparison above.

Table 6.6 clearly shows the disproportionate number of victims aged less than twenty years old and those above sixty years, giving a situation where in excess of 50 percent of injuries occur to 20 percent of the farm workforce. The extremes in the older and younger age groups raise the possibility of a lack of training, experience and understanding of the hazard on the part of the younger workers, and loss of agility on the part of older workers.

Interestingly, the age range least likely to be involved in a tractor run-over injury event is the 20-29 year old group, although this group is high in the farm worker age breakdown. Indeed, it is only among those less than twenty years of age, and those over sixty that the percentage of run-over victims is greater than the percentage of farm workers.

Figure 6.5: Age range of run-over victims, Australia, USA and Canada.



The graphical presentation of available data relating to age of victims of run-over incidents in Australia, USA and Canada in Figure 6.5 highlights the high incidence of young children identified as being involved in tractor run-over incidents in Australia. This striking difference in reported tractor run-over injury rates in young children in Australia compared to the United States of America and Canada warrants investigation, with the initial aim of determining whether the lower rate of young victims in the data reported from North America is a result of the definitions and methods of data gathering, or whether there exist superior farm safety systems and promotion methods in place in North America.

There is evidence of aggressive promotion of child safety programs in North America, such as safety promotion clubs and safety promotion day camps, which may have successfully influenced the childhood injury rate, although the exemption of agriculture and farm children from regulatory safety controls might suggest that the differences relate to the datasets being used.

Gender

Although it has been possible in many cases to identify victims as either male or female, this is of little significant statistical relevance as it is not possible to ascertain total numbers of females in the rural workforce. There is also a lack of statistical information indicating the number of people ‘at risk’, ie workers, farm owners, farm families, farm visitors, etc. Consequently no attempt has been made to relate the number of victims to population levels other than as shown in Table 6.4.

Work practice

Analysis of most injury events reveals that work practices have been a factor to at least some degree. Analysis of the 215 tractor run-over injury incidents studied in this project revealed that in every case at least one person performed an action, or allowed another person to perform an action, which was a factor in the lead-up to the event.

Table 6.7: Mechanism of tractor run-over incidents in Australia.

Victim status	Fatal	Non-fatal	Total
Co-worker	10	13	23
Bystander	13	10	23
Passenger fell off	23	17	40
Passenger mounting	3	0	3
Operator standing beside	13	24	37
Operator mounting	15	11	26
Operator dismounting	6	3	9
Operator starting from ground	8	14	22
Operator fell off	5	8	13
Unknown	15	4	19
Total	111	104	215

From Table 6.7 it can be seen that in total there were 43 passenger victims, 46 bystander/co-worker victims, and 107 tractor operator victims. Of these, 27 of the passenger victims and 19 bystander victims were below ten years of age.

Tables 6.7 and 6.8 clearly indicate a number of areas where work practices have been a factor in the events leading up to incidents.

Table 6.8: Status of victim of tractor run-over incidents in Australia.

Victim status	Number of victims	Comments
Bystander or co-worker	46	23 persons assisting in the work, and 23 bystanders, were identified in the data. Of the 23 bystanders, 19 were aged less than 10 years old; two were older children, and two adults. Six of the incidents involving children under ten years old were non-fatal, and thirteen were fatal.
Passenger falling off tractor	40	40 cases involved passengers falling off a tractor. In no case was a suitable seat, with restraint, fitted to the tractor. At least three of the incidents involved a tractor fitted with an enclosed cabin. 27 of the victims were below ten years of age, of which 12 died.
Passenger mounting tractor	3	These events occurred when bystanders attempted to obtain a ride by mounting a moving tractor.
Operator standing beside	37	6 cases occurred when the dismounted operator incidentally knocked the tractor into gear, 23 were the result of failure of the handbrake or failure to apply the handbrake, and the causes of 8 events are unknown.
Operator mounting	26	Two of these incidents occurred when the operator dismounted from a slowly moving tractor, and then tried to remount. Twenty-one resulted from failure of the handbrake or failure to apply the handbrake, allowing the tractor to roll, and the operator was run over while trying to mount the runaway machine. Three events are of unknown cause.
Operator dismounting	9	Seven events resulted from operators dismounting from a moving tractor, and the operator knocking the tractor into gear while dismounting caused two.
Operator starting from ground	22	Twenty-one incidents were caused by the operator standing beside the tractor to start the engine, either by use of the start switch or by shorting the starter terminals. One incident resulted from the operator starting the machine by use of the crank handle while the gear was engaged.
Operator fell off	13	Insufficient information is available in most case reports to ascertain why the operator fell from the machine. A cow that he was leading by a rope pulled one operator off his tractor.
Unknown	19	These events did not have all information available, i.e. status of victim, mechanism of the event, etc.

Bystanders to hazardous work

Eighteen children aged less than 10 years were killed or injured because of being in a work area where tractors were operating.

Two older children and two adult bystanders were also involved in incidents because they were in the work area.

Co-workers were frequently involved in incidents because of stepping in the path of the machine from behind crates etc. where the operator could not see them, or from being in an area outside the operators vision because of loads attached to or carried by the tractor, or a blind spot arising from the design of the machine.

Passengers on tractors

Forty-three incidents were the result of passengers being allowed to ride on the tractor. Twenty-six of these victims were below 10 years of age. Suitable seating with restraints was apparently not available for passengers in any of these events. Three of the victims were actually trying to mount a machine while it was in motion, with a view to obtaining a lift.

Operator standing beside tractor with engine running, knocking the machine into gear

Six cases involved the operator, while standing beside the tractor with the engine running, bumping the gear lever, knocking the machine into gear.

Failure to apply handbrake

Thirty-nine events were the result of the operator failing to apply the handbrake, or failure of the handbrake to hold the machine. Handbrake failure generally arises as a result of poor maintenance practices.

Dismounting/ remounting while tractor moving

Two incidents occurred when the operator dismounted while the tractor was moving slowly with the gear engaged, and then tried to remount the moving machine.

Seven events resulted from the operator dismounting while the tractor engine was running.

Starting tractor while standing on the ground, rather than on seat

Twenty-two operators were injured as a result of starting the tractor while standing on the ground, rather than from the operators seat.

Almost every incident history studied demonstrated that poor working practices were a factor in the events leading up to the occurrence that caused the injury. Indications are that the farms where the incidents occurred did not have safe work policies in place, or if policies did exist they were not enforced. Farmers need to be aware that the tractor is designed to perform tasks as a power source for implements, and no provision is made for passenger carrying.

Overall, 67 children under the age of 15 years were involved in incidents, 33 % of the total, many being victims of work practices that allowed them to be on or near a farm tractor while it was in operation.

Training

The limited information available relating to these incidents did not, in most cases, include details of the experience of the tractor operator.

6.2 Risk factors relating to the machine

The scarcity of information available in most incident reports does not allow an accurate assessment of the influence of machine factors on the result of the incident. The data that is available, supported by findings of previous research projects, does allow a number of assumptions to be made with some confidence.

- The large number of victims who were standing, or who fell, between the rear and front wheels demonstrates the potential danger of having open access to this area of the machine.
- Access to tractor operating platforms is, in most cases, inside the track of the tractor wheels.
- Suitable handrails and handgrips are not always available.
- Run-over incidents involving bystanders or co-workers frequently occur as a result of ‘blind spots’ around the tractor, where the operator cannot see people, especially children, who may be in the danger area.
- The frequency of incidents involving the operator failing to apply the handbrake, or failure of the handbrake, allow the probability of a design factor that makes application and/or maintenance of the handbrake difficult. This problem may be more common on older model tractors, however insufficient data is available to prove or disprove this.
- Bypass starting incidents result from a failure to have a suitable interlock system fitted and operational, to prevent the tractor from being started while the gears are engaged. The occurrence of such incidents also requires the starter motor to be accessible for ‘jump starting’, or the start switch to be accessible from the ground. This action in most instances is related to the machine owner failing to maintain the tractor to a safe and reliable level of efficiency.
- Few, if any, tractors are fitted with a satisfactory passenger seat, with seat restraints, mounted within the safety structure of the ROPs or FOPs. Several tractors are marketed with a small seat fitted next to the operator’s seat, which appear to have been designed for use by children. There is room for doubt as to the compliance of at least some of these with plant regulations.
- Many tractors, although fitted with ROPs, do not have a seat belt fitted. There is an almost universal failure on the part of operators to use a seat belt on those tractors where it is available.
- The transmission change lever in some models is situated in such a position that the operator may inadvertently move it while mounting, dismounting, etc, resulting in a gear being selected.

6.3 Risk factors associated with the operating environment

Insufficient information was available to determine the environmental factors present for most incidents. It was established that 68 incidents occurred in a field, eight in an orchard or vineyard, 11 in a farm shed or packing shed and five on a farm road. The incidents in farm sheds involved three operators, two child passengers, one adult passenger and five child bystanders.

Slope of the ground was a secondary factor of many of the incidents in which the tractor moved owing to handbrake failure or failure by the operator to apply the handbrake.

Four of the reports concerning victims falling or being thrown from a tractor made mention of rocky ground, or bumps as being a factor.

The environmental factors, in general, are a part of normal farm activities, and there is usually little that can be done to remove them. The emphasis in hazard reduction must be on methods of avoiding

environmental hazard factors by such means as establishing good work practices or improving tractor design technology so as to reduce the effect the environment may have.

6.4 Injury outcomes

The insufficient recording of relevant data regarding tractor run-over injury events results in a lack of information on the nature and location of injury. The information that is available indicates that the most common injury in non-fatal occurrences is crush or fracture in the area of the lower body and legs. Fatal injuries frequently occur to the head and chest areas, generally crush injury. These findings agree with results of overseas research (eg CAISP (2001), Farm Run-over Injuries in Canada, 1990–1994).

Figure 6.6: Nature of injury resulting from tractor run-over incidents.

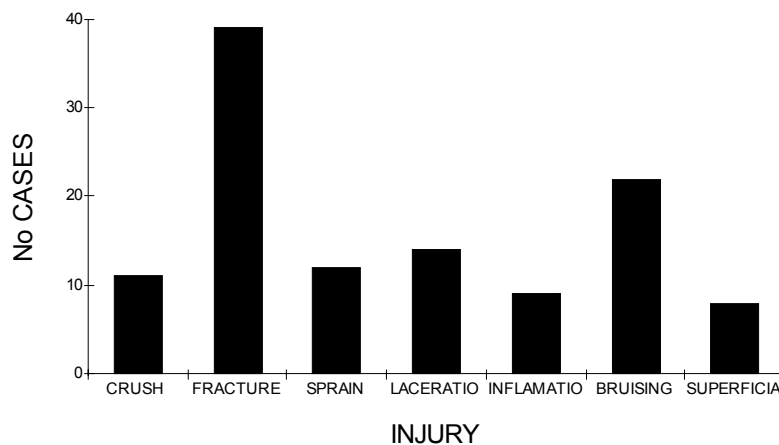
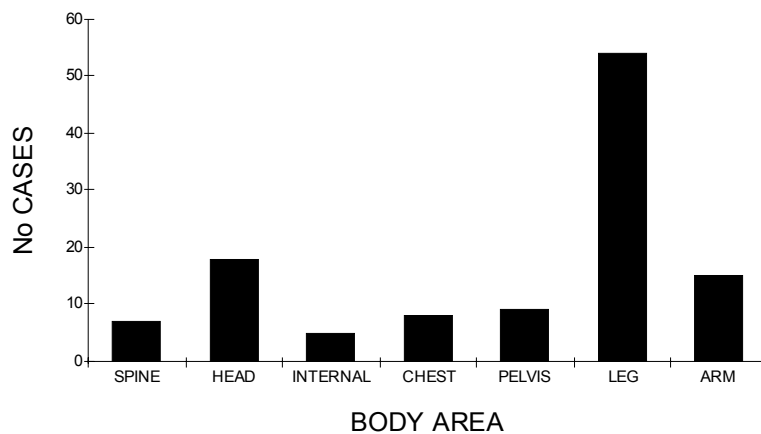


Figure 6.7: body area of injury resulting from tractor run-over incidents.



Figures 6.6 and 6.7 indicate the types of injury inflicted, and the body parts affected. These can only be considered as indicative, as data are not available for many of the incidents analysed. The data utilised for these charts refers mainly to non-fatal incidents. Some incident cases report two or more injuries. As is the case in several other areas, assumptions have had to be made based on the data that is available. Further research is needed to determine the real picture regarding injury type and location relative to the various injury events.

7. Australian Standards

The Australian Standards listed below are directly applicable to the safe design and operation of farm tractors. Some sections have been quoted where application to this project is specific, however this must not be considered as implying that other sections of the standards do not apply. There are a number of other standards that also apply to tractors, but those selected are considered to be applicable to tractor run-over safety issues.

It would appear that compliance with these standards by some manufacturers is at best cursory, and more attention needs to be given to ensuring that the required standards are met. There may be a need to revise some sections of the standards to ensure clarity, and to remove the possibility of different interpretations of some clauses.

7.1. AS/NZS 2153.1:1997 – Tractors and machinery for agriculture and forestry – Technical means for ensuring safety, Part 1: General

Section 10.1.

“Any machine on which the presence of a driver or operator is necessary, including any place to which access is required for service or maintenance, shall be fitted with handles or handholds and steps so the person has a safe, convenient means of mounting and dismounting”.

A reasonable interpretation of this standard would indicate the need for access steps to be designed so that the operator could mount from outside the wheel-track area, as mounting from between the wheels cannot be considered safe.

Section 10.2

“Means shall be provided to prevent the operator from falling from his workplace.”

This clause is generally followed on new tractors, that have either an enclosed cabin or ROPS with seat restraints fitted.

Section 10.3

“On a machine on which the operator is required to sit, a seat shall be provided which will adequately support him in all working and operating modes and prevent him from slipping off the seat.”

Section 10.4

“Pedals and controls shall be positioned so that they do not obstruct access.”

7.2. AS/NZS 2153.3:1997 – Tractors and machinery for agriculture and forestry – Technical means for ensuring safety, Part 3: Tractors

Section 3.1.3.1

“The main controls and their linkage shall be arranged or protected in such a way that the operator cannot reach them if he is standing on the ground between the tractor and the mounted implement.”

Some tractor models have the three-point-linkage external controls mounted at the rear of the seat, or on the fender, in an area that does not comply with this clause.

Section 3.3.1

“Access to the operators seat shall meet the requirements of ISO 4252 and shall not be restricted.”

“Access should minimise the probability of the operator being inadvertently restrained: i.e. catching or holding of the person or clothes should be avoided.”

7.3 AS 1246:1972 Operators controls for agricultural tractors and self-propelled machines

Serial number 17

Starter switch – “The switch should be operable from the operator’s seat, but where practicable not operable from the ground. It shall be impossible to start the engine unless (a) the gear selector is in a neutral position or (b) the transmission clutch is disengaged.”

7.4 National Standard for Plant (NOHSC: 1010(1994))

This national standard has provisions relating to the safe design, manufacture, supply and use of plant items. The principles of this standard have now been incorporated in the occupational safety legislation of most Australian states and territories.

Machine designers, manufacturers, importers, suppliers, employers, employees, and anyone who is designing, manufacturing or modifying plant must use the National Standard for Plant as a guide.

8. Discussion

The body of this report is based on an analysis of data and study of literature obtained from sources in Australia and overseas. Considerable difficulty was experienced in obtaining relevant case reports, especially for non-fatal incidents.

The very nature of rural business, which involves a largely self-employed workforce, leads to problems in recording of incident cases. Sources such as the National Data Set (NDS) of workers' compensation cases has only limited application. The data available from state occupational health and safety organisations is also of limited extent, as their incident investigations generally do not extend to self-employed injury victims.

The limitations in information available prevents a full analysis of all factors involved in each incident; for example, in only a few cases is the age, model, etc of the tractor recorded. This prevents formation of a reliable estimate of the effectiveness of safety features as fitted to later model tractors.

The data located during this project resulted in an approximate 1:1 ratio of non-fatal to fatal events. CAISP, in the report 'Farm Run-over Injuries in Canada, 1990-1994', found a ratio of 5:1, an indication that it is reasonable to assume many more non-fatal events have occurred in Australia than have been identified in this report.

Table 8.1: Circumstance of tractor run-over fatalities.

Circumstances	Australia %	Canada %
Rider run-over	16.3	23.4
Blind run-over	20.0	20.7
Unmanned run-over	47.3	35.2
Jumpstart	15.5	7.2
Unknown	0.9	13.5
Total	100.0	100.0

For the purpose of Table 8.1, in order to be comparable to the Canadian data, five cases where the operator fell off, fifteen operator mounting and six operator dismounting were classified as unmanned run-over. A more realistic breakdown of Australian data, for the purpose of determining causal factors, would be rider run-over 16.3%, blind run-over 20%, unmanned run-over 23.7%, operator fall 23.6%, jumpstart 15.5% and unknown 0.9%.

Accepting that the Canadian ratio of 5:1 is applicable to Australia leads to two conclusions: that many more tractor run-over incidents occur than is indicated by the data available, and that, even at a 5:1 ratio, the number of fatalities indicates that the injuries received in tractor run-over events tend to be severe.

Reports of cases where a supposedly parked tractor moves forward or backwards, running over the operator or a bystander, frequently make mention of failure of the hand brake, however little evidence can be found of investigations to ascertain whether there is an inherent fault in tractor handbrake design, either in particular cases or on a wider basis. Brake failure could well be a problem found only in older model tractors, however this is impossible to ascertain given the lack of data regarding age, model etc of tractors involved in injury incidents.

Seventy-two of the injury occurrences resulted from the victim standing, moving or falling in the area between the front and rear wheels. This is not a new trend: McDonald (1972) said:

“The space between the front and rear wheels of a tractor is a particularly dangerous region, as anyone occupying this space is liable to be run over if the tractor moves forwards or backwards. It is a space that is occupied relatively frequently for mounting and dismounting, and for reasonably long periods of time during servicing and maintenance. Drivers or passengers being thrown or falling from the tractor usually fall into this between-the-wheel space.”

Traditional tractor design incorporates an open frame configuration, with no bodywork outside the frame between the rear-wheel mudguard and the front wheel. In part, this was originally designed to allow the use of mid-mounted equipment such as spring-tyne cultivators. Such mid-mounted equipment is not in general use in modern day agriculture. Farmers and tractor manufacturers have argued that space is necessary in the between-wheel area to allow easy access for servicing, however such space is not provided in cars, trucks, or many items of earthmoving equipment, with no adverse effect on the ability of the operator to service the machine. Some tractor manufacturers in recent years have moved towards having this hazard area enclosed, but such an advance is by no means universal.



Tractor with open frame construction. Potential victims can fall or be standing in the area between the front and rear wheels.

CAISP, in the executive summary to the Farm Run-over Injuries report said: “The concept of farm injury surveillance which guides CAISP is much more than simply the collection of data. CAISP wants to use the information to develop a clear understanding of what causes these tragic injuries. CAISP data show that there are recurrent patterns of injury across the country. These are **not** random or isolated ‘accidents’. The word ‘accident’ does not appear elsewhere in the CAISP report. This is the same concept that led to the avoidance of the word ‘accident’ during the preparation of this current report, in the belief that using terminology such as ‘accident’ tends to reinforce the attitudes that the events are unavoidable. It is, perhaps, an extension to this that led one representative of a tractor manufacturer to say “It just has to be accepted that a certain number of accidents will happen in agriculture, and there is nothing we can do about it.”

Several sources relating to operators falling from tractors referred to the operator standing on the operators platform to relieve back pain, or even in one case standing on the side step to avoid discomfort in sitting on the seat. There is perhaps a case for further research into operators seating, mechanical vibration, noise etc, and the effect on operator comfort and alertness.

Operator comfort is not generally found in references to factors that are involved in the process leading to operator injury, thus it is not possible to speculate on the importance this factor may have. The problem could well be related to older tractor models rather than those designs currently marketed.

There is need for a research project similar to that carried out by McDonald (1972) in order to ascertain the part played by tractor design in the factors of the injury events that are continuing to occur. Such research could well provide information to permit designers, safety professionals and regulatory authorities to further reduce the influence of various factors on the operation of a tractor that may lead to an injury event.

9. Options for Risk Reduction

The continuing occurrence of tractor run-over injury events despite the extensive information available from previous investigations into the phenomena make it obvious that previous attempts at achieving a reduction in the number of incidents have not been generally successful, and that new approaches to the problem are required.

Consideration of methods of reducing the risks associated with hazards in the workplace follows the generally accepted 'hierarchy of control' framework, viz:

- Elimination – removing the hazard or hazardous work practice from the workplace.
- Substitution – substitute or replace the hazard or hazardous work practice with a less hazardous one.
- Engineering/design controls, including isolation of the hazard from workers – if the hazard cannot be eliminated or substituted engineering or improved design control is the next preferred measure.
- Administrative controls – ensuring safe work practice, labour organisation and operator skills.
- Personal protective equipment – considered when other control measures are not practical, and where it is possible to protect body parts from injury.

The higher order controls are considered to be more effective as their effectiveness is not dependent on human behaviour. Effective risk control in the workplace generally involves a combination of several control methods.

This study has identified a number of contributory factors in tractor run-over events, therefore a number of different strategies are necessary in order to combat them.

The diversity of activities to be found in a rural enterprise requires that the workforce be multi-functional, and operators in any position may not be highly experienced or trained in that field of activity. To ensure that operators with minimum experience can operate the tractor safely, every effort must be made to reduce the existence of hazards.

Formulating a risk reduction program to reduce injuries associated with tractor run-over is complex and must also be made in the context that there are thousands of tractors in use on more than 120 000 Australian farms. It will take many years for these to be replaced with safer, newer tractors.

9.1. Elimination options

Elimination of the tractor as the hazard associated with run-over risk would rarely be an option for Australian farming enterprises.

9.2. Substitution

Substitution of the tractor run-over hazard should be considered for specific tasks that pose a risk of run-over. An example can be seen in feeding out stock, where there may be other options for feeding hay than the operator mounting and dismounting the tractor moving in low gear.

9.3. Engineering/design controls

9.3.1 New tractors

The difficulty in achieving improved safety aspects in the tractor design is the complete lack of Australian manufacturers, and the problems in convincing overseas manufacturers that requirements for Australia are reasonable if they do not correspond to their local requirements, especially considering that in many instances the Australian market is a very small part of their total sales. There is need for co-operation at governmental level between countries to reach agreement on the features that should be standard on all production tractors. Manufacturers, for obvious economic reasons, avoid features that add to the production cost without creating a market advantage. Provided that the same requirements exist for all tractors being sold into all the major markets then no disadvantage exists for any manufacturer.

The part played by the designer in the reduction of hazards associated with tractor operation is crucial, and designers must recognise the necessity of incorporating design safety from the earliest stage of the design process.

Operator platform.

Analysis of the data shows that a minimum of 72 of the victims (35%), injured while bypass starting the tractor, standing beside the tractor, mounting or dismounting, or falling from the tractor, could have avoided injury, or suffered a lesser injury, if access to the area between the front and rear wheels had been denied. This area of the tractor is accessed when operators or passengers mount or dismount, for the operator to service or bypass start the tractor, and by bystanders who wish to speak to the operator. It is reasonable to assume that other victims listed as falling from the tractor fell into this area, however insufficient information is available to positively identify the area into which they fell.

In recent years new tractors on the market are frequently fitted with an enclosed cabin. Those without an enclosed cabin are fitted with rollover protection. Access to the cabin or platform may be from within the wheel track, and steps are often difficult to mount, with step and handhold design in some instances apparently not meeting the requirements of AS/NZS 2153.1:1997. The operator, when mounting to some enclosed cabins, must swing his or her body out from the vertical, while standing on the step, in order to open the cabin door.

Access to tractor cabins, or to the platform where a cabin is not fitted, should be from outside the track of the tractor wheels, and the steps should lead to a platform where the operator may safely stand while opening the cabin door. Design of the steps should be such as to minimise the risk of the operator's foot slipping, especially in wet and muddy conditions.

There may be, of course, some difficulty in designing an effective access step outside the wheel tread width for tractors with adjustable track width. This is not insurmountable, as wheels are shifted only rarely, and in many cases never shifted at all. The design of the platform must include a method of adjustment to suit various wheel track settings. Inspection of a number of current model tractors showed that the step was outside the wheel on many smaller tractors. Larger tractors tend to have the step outside the wheel track when single wheels are fitted, however the fitting of dual wheels places the operator well inside the danger zone when mounting and dismounting.



This tractor has access outside the wheel track as currently set up, but what happens when a dual wheel is fitted?

One tracked type agricultural tractor inspected had an access platform over the track, with the step leading down the front of the track. This would be an excellent design provided access to the first step was from the side of the track, rather than from in front, a minor design change that would only require a slightly larger first step, and would appear to have no detrimental effect on tractor operation.

Seat belts.

ROPs are of limited use in preventing injury to the operator unless a seat belt is worn. Any tractor which has a ROPs or FOPs, whether or not as part of an enclosed cabin, must also have a seat belt fitted. To encourage operators to wear the seat belt, it must be designed and fitted in such a way as to be easy to put on, and comfortable to wear, regardless of the build of the operator. Most incidents involving the victim being thrown from or falling from a moving tractor could have been prevented by the wearing of a seat belt. The opposite is also true; if the tractor does not have a ROPs fitted then a seat belt would only increase the hazard in rollover situations.

Tractor designers should assess the effect of all the fittings, controls, etc in the tractor cabin, as in some cases the use of a seat belt will cause the operator, rather than be thrown out, to strike against and be injured by sharp protruding objects within the cabin.

Interlock control system.

In order to prevent accidental operation of controls, skidsteer loaders are fitted with an interlocked control system. This system requires that a non-operational control such as a seat belt or restraint bar must be secured or activated before operational controls can function.

A restraint bar could easily be fitted across the door of a tractor cabin, or across the access area of the tractor in the event that a cabin is not fitted. Such a restraint bar should be designed to prevent exit from the machine until the bar is lifted away from the operational position. The action of lifting the bar should apply the brakes, neutralise the transmission, and prevent operation of hydraulic controls. This action would prevent almost all of the unmanned run-over events, and greatly reduce the injury statistics.

Some initial resistance to the fitting of such a device could be expected, however the system has been in use on skidsteer loaders for many years, and operators do not have a problem with their use.

McDonald (1972) recommended use of a handbrake lever that had to be applied before the operator could exit the cabin, a recommendation that has not been adopted by the tractor manufacturing industry.

Operator presence sensors.

The principle of fitting a tractor with a 'dead man switch', or operator-sensing device, is not new. The first patent for such a device was taken out in 1934, with the reasoning that "it frequently happens that the driver slides or tumbles from his seat to the ground and is out of reach of the ignition switch. If the implement being towed is a wide gang of ploughs, disks or harrows the fallen driver may be in danger of life or limb from the oncoming, uncontrolled implement". The design for a switch that was activated when the operator took his weight off the seat, as is used on today's ride-on lawnmowers, was patented in 1941. That these patents were considered necessary is evidence that as early as 1934 the need for such a safety device was recognised.

Except in the rare event that the tractor is being used as a stationary power source, there is no function in which the machine should be used without an operator seated on the platform, therefore the action of an operator sensing device would not be in any way detrimental to the normal operation of the tractor. Such a device could be arranged to be bypassed when the transmission was in neutral (or park) and the brake applied, to enable the operator to dismount for such actions as opening a gate without having to restart the engine, while retaining the action of stopping the PTO drive and preventing the tractor from rolling forwards or backwards.

Sensing systems may consist of a device operating on physical contact, light beams, infrared, radar (microwave) or capacitance. Each system has potential for use on agricultural tractors, although some devices are prone to false triggering under conditions met in agricultural operations.

The fitting of an operator sensing system serves three purposes, to prevent starting of the machine from the ground, to prevent the operator from dismounting while the tractor engine is running, and to stop the machine in the event that the operator should fall off. The device would not provide instant stopping of the forward (or rearward) motion of the tractor, and therefore would not prevent all instances of operator run-over, however it could be expected to save those operators who slow their descent by grabbing a handhold on the tractor, and also prevent run-over by the drawn implement.

Sensing devices also have potential to be used for detection of bystanders in the danger area, and stopping the tractor to prevent a potential injury incident. Scarlett et al, (2002) have carried out research on the application of sensors for worker protection on self-propelled harvesting machinery, the results of which may be relevant to tractor applications.

Engine access.

While it is necessary for the engine and engine components to be readily accessible to the operator and serviceman when service or maintenance is required, there is no necessity for the person to be standing on the ground during this process. Indeed, the design of some tractors is such that the serviceman must be in a position that is not ergonomically satisfactory, and provision of a platform from which to work would improve the ease of access.

A shield, or 'running board' type of body panel should extend from the cabin access platform to the rear of the front wheel so as to prohibit access to the engine starter motor or starter switch while the operator is standing on the ground.

The provision of a platform as outlined above would also prevent persons who fall or are ejected from the tractor from falling in front of the rear wheel.

A small number of the tractor models currently on the market do have the between-wheel area enclosed.

Operator's controls.

Incidents (6 identified in this project) result from the operator bumping the gear control lever while mounting or dismounting from the tractor. Gear controls should be mounted in a position where a person entering or exiting the operator's platform cannot inadvertently move them. The position of the gear control when the transmission is in neutral or park position should be such that it cannot be moved by being bumped by the operator, and cannot engage the gears because of movement caused by tractor vibration.

In order to prevent unintentional starting of the tractor, especially by children who may enter the machine unnoticed, the starting system should consist of two keys or press buttons situated in such a manner that two hands are required to operate them, at a distance apart that young children could not reach both, and in a position that both could not be reached by a person standing beside the tractor. The system would require simultaneous operation of both switches.

The engine stop control should be held in the stop position in a positive manner. An emergency stop control should be mounted on the left (near) side of the tractor such that it may be reached by a person standing beside the machine outside the track of the wheels.

There have been reports of operators lowering the three-point-linkage mounted implement to hold the tractor from rolling forward or back, then dismounting to adjust the implement. They then use the externally mounted control to lift the implement, allowing the tractor to roll and run over them. Australian and New Zealand Standard AS/NZS 2153.3:1997, paragraph 3.1.3.1, states "The main controls and their linkage shall be arranged or protected in such a way that the operator cannot reach them if he is standing on the ground between the tractor and the mounted implement." There is a need for this clause to be enforced to prevent incidents of the type mentioned, or operators being crushed between parts of the implement and the tractor. Some current model tractors do have the auxiliary hydraulic controls mounted on the tractor mudguard to enable the operator to adjust three-point linkage or implement settings from the side of the tractor.

Reverse warning system.

Tractors, especially those working around packing sheds or in similar areas where pedestrians are common, should be fitted with a reverse warning buzzer. A reverse warning buzzer is a common requirement for trucks and earthmoving equipment, and could easily be fitted to agricultural tractors. There is some evidence that audible warning systems have limited effectiveness in working environments where they are constantly in use, or where a number of machines are working, owing to the workers becoming accustomed to the noise to the point where they effectively block it out, however this possibility should not prevent the fitting to tractors.

Rotary flashing lights.

Rotary flashing lights have coloured lenses, and are usually mounted on the top of the tractor cabin. These devices are very successful as a warning system in areas where the tractor is working in proximity to other workers. Like acoustic systems, there may be a tendency for people to become accustomed to the lights and not notice the warning.

Radio sensing device.

Radio sensing devices have been developed for the coal mining industry, and are at this time quite expensive. They become activated by the operator selecting reverse gear, and an alarm inside the cabin alerts the operator in the event of a pedestrian being within thirty metres of the rear of the vehicle. Such a device may be warranted in areas where tractors are frequently working in proximity to other workers. Further development may reduce the cost of the unit, and allow more common use on tractors.

Neutral start switch.

The neutral start switch, which is designed to prevent operation of the engine starting system unless the transmission is in neutral, is subject to misuse by the operator disconnecting the sensor, and connecting the terminals so as to ensure that the starter may be operated at any time. This is sometimes done in order to bypass a faulty switch. The switch could well be interlocked with another function, such as a brake lock, in such a way that bypassing the switch would immobilise the tractor. The system could effectively prevent movement of the tractor once started, until such time as moving the transmission lever from the neutral or park position to engage a gear turned off the neutral safety switch.

Braking system.

Twenty-one incidents were identified as having handbrake failure or failure to apply the handbrake a factor leading to the tractor moving while unmanned.

Handbrake systems should be designed to allow easy application by any operator, regardless of physical size and condition. The handbrake must be positively held in the applied position in such a manner that the latching mechanism is not compromised by normal wear or build-up of dirt etc. around the locking mechanism. This problem may be restricted to older tractor models, however this cannot be determined by analysing available evidence.

Tractor suspension.

The effect of having a tractor mounted on an active suspension system does not appear to have been the subject of any safety engineering research. There would, however, appear to be two positive effects of having a suspension fitted: the driver could reasonably be expected to become less fatigued from the effects of mechanical vibration, and the suspension would dampen reaction to sudden changes in the traction surface, such as potholes, resulting in a reduced tendency for ejection of the operator from his seat.

The use of an active suspension may be detrimental for some operations for which the tractor is used, in particular in the case of high power machines.

Visibility.

Tractors tend to have a number of blind spots where the operator cannot see any person who may be present, especially a small child. Designers and manufacturers must make every endeavour to eliminate such blind spots.

A number of manufacturers have made creditable progress in this area in recent years, by such design innovations as dispensing with the traditional highline radiator, thus allowing the fitting of a sloping bonnet that greatly increases visibility to the front of the tractor. It is considered that further attention is necessary to improve general visibility around the tractor. The fitting of improved rear vision mirrors would improve visibility on many tractors. There may well be advantages in fitting a closed circuit television system as is used in some industrial mobile plant, to cover those areas not readily visible to the operator.

The custom of fitting large saddle type or front mounted chemical spray tanks to tractors, as commonly seen in cropping areas, creates a visibility problem which must be recognised by operators, and compensated for by increased alertness. Farmers, when compiling a safe operation procedure for such tractors, must ensure that they are not operated in any farm area, including around farm sheds etc, where bystanders, particularly children, may be present. There does not appear to be any research data available on the safety aspects of fitting aftermarket equipment such as saddle tanks.



Chemical tank mounted in front of tractor obstructs operator's forward vision

Cabin security.

There is a widely held belief that a modern tractor fitted with an enclosed cabin is safe for children to be carried as passengers, however examination of injury data shows that a number of children have been injured as a result of falling from a tractor when the door has unexpectedly opened. There have also been cases where the victim has fallen when the glass window against which he was leaning has dislodged from the frame. Door catches need to be of a design that is difficult for children to open, with a minimum requirement that the direction of movement to open the door is upward rather than downwards or horizontal.

9.3.2 Modification of existing tractors

The data available do not extend to information regarding the make, model, etc of the tractor relative to each incident, thus it is not possible to ascertain whether older tractors are more likely to be involved in injury events than new models. There is some evidence, however, that older tractors do present a greater hazard, as would be expected.

A program designed to reduce the frequency and severity of injury from tractor run-over will have little effect without a component aimed at bringing to the notice of farmers and farm workers the dangers of older tractor operation, and the possibility of carrying out modifications to the tractor to reduce that risk.

Farmers using older model tractors should be encouraged to consider modifications designed to upgrade the safety aspects of their machine. Planned modifications must be assessed to ensure that the modification itself does not introduce new safety hazards, and engineering advice should be sought by farmers who do not feel confident to carry out such a risk assessment themselves.

The obvious need for modification to older tractors must not be allowed to mask the possibility that improvements may be possible to enhance the safety of even the latest model machines, and to adapt them to work more safely in specific job environments.

Consideration should be given to the concept of a cost rebate scheme for modifications that have a high potential for preventing serious injury, such as fitting of a safe access platform. Such a scheme could be operated along the lines of the rebate scheme for fitment of ROPs that has operated successfully in some states of Australia.

Operator platform.

Older model tractors generally have no operator protection and cluttered operator platforms, together with poorly designed access and steps. To achieve a reasonable level of safety these machines should be fitted with an approved rollover frame, and where possible seat belts should also be fitted.



Older model tractors frequently have a cluttered operator's platform, with poor access and egress. The machine may not have a certified ROPS fitted.

The access to the operator's platform should be assessed, and if found to be below an acceptable standard a safe access platform must be fitted. Information relating to the construction of such a platform is available from The Australian Centre for Agricultural Health and Safety (Safe Tractor Access).



Access is from in front of the rear wheels. A safe access platform is necessary to reduce the run-over hazard.

Source: Australian Centre for Agricultural Health and Safety. Safe Access Guideline



The same tractor with a safe access system fitted. The operator mounts from outside the wheel area. A person falling off the tractor cannot land between the front and rear wheels.
Source: Australian Centre for Agricultural Health and Safety. Safe Access Guideline

Design of safe access should include a method of preventing access from the off side of the tractor.

The fact that possibly 35% of tractor run-over victims could be saved from injury or have injury severity reduced by the fitting of safe access should place widespread promotion of the benefits of safe access as a high priority for farm safety programs.

Operator seat restraints.

Whereas the fitting of ROPs to older tractors is now mandatory in many states of Australia, the fitting of an operator restraint is not always carried out. Putting aside the fact that the mere fitting of ROP will only lessen the risk of being crushed in a roll-over event, not prevent the operator from being dislodged and crushed, it does nothing towards preventing the operator falling or being thrown off the tractor and run over.

Tractors which are fitted with ROP or FOPs should always also have a seat belt fitted.

The following provisions of the Health and Safety at Work Act in the United Kingdom have been interpreted as providing a requirement to wear seat belts where there is a foreseeable risk of injury from not wearing them:

- Employers have a duty to ensure, so far as is reasonably practicable, the provision of information, instruction, training and supervision to ensure the safety of their employees at work.
- The self-employed have a duty to conduct their undertaking so as not to expose themselves to risk.
- Employees have a duty to take reasonable care for their own health and safety.

The similarity of these provisions to those in Australian legislation allows a possibility of similar interpretation.

Starting systems.

Twenty-one of the incidents investigated occurred to operators who were standing beside the tractor to start the engine. While some of these may have been reaching in to the key start, many were 'jump starting' the engine. This is a common practice on older model tractors, where starting systems deteriorate and batteries are often old and inefficient. The usual practice is to short across the starter motor terminals with a screwdriver or similar tool, thus bypassing the neutral safety switch if one is fitted. To prevent this dangerous practice a guard should be fitted to prevent access to the starter motor electrical terminals.



The electric starter motor is easily accessed by the operator. This tractor may be jump-started by the operator while standing between the wheels.

Interlock control system

The fitting of an interlock control to older model tractors, while possible, would not be practicable in most instances. Farmers should give consideration to this modification for certain machines which are commonly used for purposes that have a high risk of operators dismounting from a moving machine, such as feeding stock.

Operator presence sensor

The fitting of an operator presence sensor, like the interlock control, would not be practicable in most instances, except for some machines that have a high risk factor.

Audible reverse warning

An audible reverse warning could be fitted to most tractor models at a reasonable cost, and would be effective in raising the safety of operating the machine in enclosed areas and other jobsites where machine/bystander interaction is common.

Revolving flashing light

Fitting of a revolving flashing light is essential for any machine operating in proximity to other workers or bystanders, especially in areas such as packing sheds.

9.4. Administrative controls

Work practice

The first essential for farm safety is for the farm to have a written safety policy, and for instruction in that policy to be a part of worker induction training. Family farms, where no employees are used, still require a policy with which all family members are conversant, and relevant parts should be explained to visitors to the farm who may be exposed to hazards.

The data demonstrate an increase in risk of an injury event in older workers. It is important that older workers, and their supervisors in the case of employees, recognise and acknowledge that aging will take its toll on their ability to react quickly and appropriately to sudden hazard events.

In order to compensate for the aging process older workers should not work long shifts, and should take more frequent rest breaks than their younger co-workers.

Passengers.

Few, if any, agricultural tractors are equipped for carrying passengers. There is a requirement, before carrying passengers, for the tractor to be fitted with a complying seat and seat belt, and generally tractor cabins do not have sufficient space for such fitment. It has been observed that several tractors are marketed with a passenger seat, generally only of a size to suit a small child. These seats in many cases do not appear to comply with the plant regulations regarding security of the seat, and placement within the safety frame.



Some older model tractors were fitted with wide seats. These seats do not meet current requirements for carrying a passenger on a tractor. This tractor should have a ROPS fitted, however it is not practicable to fit seat belts

A dilemma which tractor driver trainers have in common with those training earthmoving equipment operators is that to meet occupational health and safety regulations learner drivers must have an Instructor on the machine while they learn to drive, but no machines are fitted with a seat to allow them to legally ride. Dangerous though it may be, driver training may be the exception that will necessitate carrying a passenger.

It is universally recognised by agricultural safety experts that carrying a passenger on a tractor has a high likelihood of leading to an incident, yet farm operators constantly ignore the warnings.

It is necessary for all farm managers to implement, and strictly enforce, a no-passenger policy for all tractors and machinery used in their enterprise.

Children

The available data establishes rural children as being major stakeholders in the area of tractor run-over injuries. The fact that 33% of the victims identified in this project were below the age of fifteen years, and 25% below ten years, is stark evidence that action is required to reduce the exposure of children to the hazards presented by farm machinery, and tractors in particular.

Exposure of children to run-over hazards is largely related to the carrying of passengers on tractors, discussed previously; there is also a number killed or injured as bystanders, put at risk purely by their being allowed to enter the work area. Farm safety educational materials must be designed to emphasise the very real danger presented by children being allowed in farm work areas, and farm policy should be to restrict children to safe areas. Promotion of the concept of safe play areas on farms should be a priority action, to encourage farmers to establish an attitude of separation of children from the working areas of the farm. While it may be argued that farm children are aware of the dangers, this is not supported by the statistics, and there is the danger that visitors children do not have any understanding of the hazards posed by the farm work environment.



Children being carried as passengers on a tractor are at risk of death or serious injury.

Very young children, whether farm raised or not, have no concept of the hazards abounding on a farm. Farm machinery, especially the tractor, has a fascination for them because of the noise and movement, and because their daddy drives one.

This fascination can lead them to be near, or under, a tractor or implement without being seen by the operator. Farm children must have a safe play area, with a self-closing childproof gate, to enable them to play safely without danger of wandering into the path of farm machinery.

Lee et al, (2002), in reference to the problems in introducing safety factors regarding farm children in the United States said:

“There is strong disagreement among various stakeholders regarding recommendations to adopt stricter regulations protecting children from agricultural hazards. Parents believe it is their right to have final authority regarding their children’s work and presence on a farm worksite”

“In contrast, safety advocates endorse a public health approach to injury prevention including education, engineering and public policies.”

“Collectively, parents, farm owners and safety advocates all acknowledge that children and adolescents are dependent upon adults to set and establish protective standards for them.”

“At the very least, the recommendations of this group point to the need to establish practices and policies that enable parents to provide a safe environment for their children, ensuring that safety is viewed as a valued component of effective parenting. Ideally, the combination of research-based exposure limits, injury data, and lessons learned from other young worker safety initiatives would provide the basis for upgrading current policies (or proposing new policies) that are understood and accepted by parents and farm owners.”

The Farmsafe Australia Child Safety on Farms program has identified tractor and machinery run-over as a key hazard of high risk for Australian children, and has defined the following controls as having sufficient evidence of effectiveness for inclusion in the national campaign to reduce child deaths and serious injury on farms (Fragar et al, 2003):

Recommendations for intervention to reduce risk of serious injury and death associated with farm tractors and machinery are based on the available information that has defined the circumstances of machinery related deaths on Australian farms, the developmental characteristics of children in this age group and the literature on available intervention measures. The evidence supports the following interventions for children aged 0-14 years:

- Where possible eliminate farm machinery hazards from the children’s environment. This will only rarely be an option.
- Fence the house yard to separate the farm workplace from the place where children live, play and generally undertake their recreation, with self latching gates – create a safe place to play. Note that this is the recommended intervention to reduce toddler drowning deaths.
- Establish and maintain family and workplace rules relating to:
 - The boundaries within which children can be without parental supervision
 - Ensuring that the home yard gates are kept closed and maintained.
- Establish and maintain family and work rules relating to ‘No extra rider’ on tractors and other mobile plant and machinery. No passengers on tractors should be the focus for prevention of injuries associated with farm machinery to children on farms. The evidence shows that the majority of child fatalities relating to tractors resulted from the child riding as a passenger, falling from the tractor and being hit/run over by the tractor or attached implement (Franklin et al, 2000).
- Adults and older children on farms should be trained to undertake cardio-pulmonary resuscitation

When older children begin to engage in farm work, they should be trained to undertake farm work in accordance with their developmental and physical capabilities, and under close supervision. Parents need knowledge of cognitive, physical and behavioural characteristics of child at each stage, AND an accurate perception of risk. Section 11 of this report is devoted to the issue of children’s physical and cognitive development related to farm work.

Protection of children as young trainees should include:

- Where possible the elimination of hazards associated farm machinery.
- Effective guarding of exposed moving parts, or isolation of operators from those hazards.
- Safe tractor design features including ROPS and safe tractor access, outside of the path of the rear wheel.
- Adequate induction, training and close supervision of working trainees.
- Hearing protection when children are in the vicinity of hazardous machinery noise.
- Respiratory protection when children are in the vicinity of hazardous dusts.

Bystanders

Work practices should not allow any person who is not actively involved in the operation to be within the work area. Workers assisting the operator must ensure that they are not in a position where the operator cannot see them, or where they may be run over in the event of the tractor moving unexpectedly.



Maintenance

Lack of maintenance was a contributing factor in many of the incidents studied. Incidents caused by the operator starting the machine from the ground may generally be attributed to faulty starting systems, and many of the operator run-over scenarios can be directly related to faulty brakes.

It is possible that other maintenance problems, such as failure to replace broken rear vision mirrors, may have been a contributing factor in some incidents.

Education programs need to emphasise the absolute need to maintain machinery to optimal working condition in order to minimise hazards, and to meet the statutory requirements.

The financial benefits of obtaining maximum efficiency from a machine far outweigh the savings of poor maintenance practices.

Restricted work areas

Several of the incidents occurred when the victim moved from behind an object such as a produce bin, out of the range of vision of the operator, into the path of the tractor. Work practices should be such that workers and bystanders are clear of restricted areas when a tractor is operating. Packing sheds, etc, should have clearly marked lanes for pedestrians away from tractor operating areas. Children should be excluded from these restricted work areas.

Pedestrians should be isolated, wherever possible, from traffic areas used by tractors. Pedestrians who are in a traffic area should wear coloured or reflective clothing to enable them to be seen by tractor operators. Blind corners may require a reflector mirror.

Workplaces that have pedestrian workers in proximity to tractor operations should have in place an operating procedure similar to the forklift traffic management plan developed by Worksafe Victoria.

Presence detection systems

Enterprises, such as fruit packing, where a tractor is required to operate in and around sheds and other buildings in the presence of other workers and/or bystanders should be fitted with a form of warning system to alert pedestrians of its proximity. One such system consists of an infrared light emitter fitted to the tractor, which activates a sound and flashing light alarm when the machine is in the near vicinity of a receiver. A number of receivers may be situated around the shed or in any place where pedestrians may be in danger of being run over by the tractor. The receivers detect the beam from the infrared light at a range of several metres to activate the alarm.

Shutske et al, (1998), at the University of Minnesota, have carried out experiments in the use of passive infrared and microwave sensors mounted on a tractor, the aim being for the device to stop the machine in the event of a person entering the sensor detection area. Although focussed on PTO driven implement hazards, the principle, if proved successful, could well be adapted to warning the operator of persons in the hazard areas around the tractor. The Health and Safety Executive in Great Britain have carried out similar work.

Operator

The Safety Policy for farm tractor operation must contain clear guidelines for the operator to follow. The following must be included:

- No passengers allowed on the tractor unless an approved seat and seatbelt is available.
- Where a passenger seat is available passengers may only be carried when necessary for work purposes.
- No children to be allowed in the work area.
- The operator must wear a seat belt at all times when operating the tractor.
- Bypass starting must not be carried out at any time.
- The operator must not dismount from a moving tractor at any time.
- The tractor transmission must be placed in neutral or park and the handbrake applied before dismounting from the tractor.
- Hydraulic implements and attachments must be lowered before dismounting from the tractor.

9.4.1. Work environment

A number of the incident reports referred to factors such as the tractor travelling over a bump or hitting a stone with a wheel, or the operator slipping because of wet muddy conditions. While environmental factors such as these may be a contributing factor in some incidents, it must be realised that by the very nature of the work for which it is designed such an environment will be encountered in the normal course of events. The environment, generally cannot be changed, therefore tractor design, operator training and work practices must be aimed at reducing to a minimum the affect that such factors can have. Farmers have a responsibility to ensure that farm roads are maintained in optimum condition.

The severity of the injury resulting from a tractor run-over incident is frequently exacerbated by the time between the occurrence of the incident and the rescue of the victim, often because the victim is the only person on the site. Communication systems are necessary to enable the victim to call for assistance, however the victim may not be able to reach the radio etc, if available, owing to the injury sustained. Farm workers and family members should be encouraged to attend a first aid course to enable assistance to be available to the victim. Farm first aid courses should include training on such things as disentanglement of the victim from a PTO shaft, etc.

Education and training

Well-planned education programs are an essential element in any program proposed to reduce the frequency and severity of injury incidents. Indeed, farmer education is probably the most important element, but the most difficult to effectively plan and implement.

Education programs are necessary for a target audience of all those actively involved in the use of tractors in agricultural pursuits – farmers, farmhands, contractors, rural youth, rural women, sales personnel and suppliers. There is a need to focus on youth, as being more receptive to new ideas, and having some influence over the acceptance of safety concepts by older workers. Rural women, also, should be a primary target segment, both because of their active participation in farm activities and their influence over the attitude of their families, and also because there is reason to believe that women tend to be more receptive to safety education.

Hobby/part time farmers should be a focus area for education, because of a lack of training and experience by many participants, and the purchase of second-hand older machines with fewer safety features by this group.

Training should address the issues of the hazards of tractor run-over, and the work practice requirements described above.

10. Recommendations

The following recommendations have been formulated in accordance with the aims set this project, with the intention of providing guidance for tractor designers, manufacturers, suppliers and end users, farm families, regulatory bodies and agricultural advisors, to plan and implement programs designed to reduce the risk factors associated with tractor operation, and thereby to bring about a reduction in the frequency and severity of tractor run-over traumatic injury.

10.1. Design/manufacture

- 1 Tractor manufacturers should be encouraged to incorporate into tractor designs, systems to reduce risk of tractor run-over. Feedback on all aspects of the operation of their products, including safety hazards that become apparent in field operation, should be encouraged.
- 2 Tractor designers and manufacturers should be encouraged to provide safe access on all new tractors, allowing access only from outside the wheel track, and preventing access to the electric starter motor while standing between the wheels.
- 3 Manufacturers should be required to fit an interlock control system on all new tractors preventing egress until the controls are locked in a safe position.
- 4 All new tractors should be fitted with an audible reverse warning device.
- 5 Cabin door latch handles should be operated by lifting upwards, or otherwise designed to minimise inadvertent opening.
- 6 An emergency stop control should be fitted in a position accessible from outside the wheel track area of the tractor.
- 7 Tractor designers should continue to improve operator visibility.
- 8 Manufacturers should address the run-over risk in Operators Manuals, and provide practical advice to reduce operator risk.

10.2. Suppliers

- 1 Suppliers of tractors should ensure that safety information is provided to buyers

10.3. Existing tractors

- 1 A cost rebate scheme should be instituted for farmers fitting safe access systems to older model tractors.
- 2 All tractors should be retrofitted with ROPs and seat belts.
- 3 Farmers should be advised to fit a guard to older model tractors to prevent 'jump starting'.
- 4 Tractors operating in restricted areas should be required to be fitted with an audible reverse warning device.
- 5 Farmers operating in restricted areas such as packing sheds should be encouraged to investigate the use of tractor/worker detection systems.

10.4. Guidance material

- 1 The current Australian Centre for Agricultural Health and Safety Guidance Note No 2: Tractor run-overs, should be reviewed and revised to provide practical guidelines for reducing risk of run-overs on farms. Information should include practical guidelines for retrofitment of tractors and for safe work practice.

10.5. Education and training

- 1 Current tractor safety training competencies and resource material should be reviewed and updated to ensure that protection from tractor run-over risk is addressed effectively.

10.6. Standards.

- 1 The relevant standards should be reviewed to ensure that the content is not ambiguous, effectively reduces run-over risk and is relevant to current technology.

10.7. Regulation.

- 1 New model tractors should be inspected to ensure compliance with plant regulations in all states of Australia.
- 2 Tractor operators licence system should be considered for development and implementation similar to the requirements for plant operators.

10.8. Promotion.

- 1 A media campaign should be carried out to publicise the benefits of fitting a safe access system to tractors.
- 2 A media campaign should be devised to focus farm workers on tractor run-over hazards, demonstrating the economic cost of tractor injury events, and the advantages of safety features. This campaign should emphasise the high risk of tractor run-over injury to young children.
- 3 Farm safety education programs, such as 'Managing Farm Safety', should continue to be developed and made available to agricultural workers.
- 4 Hobby/part-time farmers should be a priority target for education programs.

10.9. Research.

- 1 A research program should be carried out with the aim of developing a practical operator sensing system for use on agricultural tractors.
- 2 A research program should be developed to investigate the advantages and disadvantages of active suspension for agricultural tractors.
- 3 The use of front and saddle mounted chemical tanks should be investigated with a view to determining the hazards presented by such equipment, and to recommend design requirements or alternative designs.
- 4 An in-depth study of tractor accidents similar to that carried out by McDonald (1972) should be carried out with a view to determining hazards present in current production tractor models..
- 5 The farming community should develop an incident reporting system to ensure that reliable data is available for future research projects.

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