DEFINING FARM-SAFETY RESEARCH PRIORITIES AND ADJUSTING FARM INSURANCE PREMIUMS BY A RISK ANALYSIS APPROACH

by

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(ABSTRACT)

A risk analysis approach for farm work-related injuries was proposed. For this study, risk is defined as the Expected Injury Cost (EIC) index per farm worker per year. Four steps are involved in the risk assessment analysis of farm injuries: (1) determination of risk factors, (2) injury severity classification, (3) cost estimation, and (4) risk characterization. Farm variables were examined to determine their influences on the rates of occurrence as well as the severity of injuries. Farm injuries were correlated with the risk factors of employment status, gender of farm worker, age of farm worker, hours of exposure, type of agricultural operation, and various hazardous conditions on a farm. By combining the probability of injuries due to a particular risk factor with the estimated costs of injuries, the EIC indices were derived for farm workers and activities.

Agricultural safety education and research priorities were defined based upon the risk model developed in this study. A sensitivity analysis was conducted to determine the impact of the assumptions on the research priorities established. It was found that the research priorities were not affected by the uncertainty on the magnitude of injury costs and other variables used in this study.

The risk-based approach can also provide input to farm insurance ratings. By combining the EIC index for each worker with the number of workers employed on a farm, a composite risk factor could be obtained for the farm enterprise. This composite risk factor can be used as a basis for adjusting farm insurance premiums. Adjustment of insurance premiums or related benefits could be used as an economic incentive to encourage adoption of safer farming practices so that preventable farm accidents and human suffering can be reduced. Other potential applications of the risk model presented in this study include safety management and loss control for a farm enterprise, and serving as a guide for the systematic collection of farm injury data.

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Chapter 1

Introduction

For the last twenty years, agriculture has been one of the most hazardous occupations in the United States. The 1990 National Safety Council data (1991) indicated that the agricultural industry had the second highest accident death rate with 42 fatalities per 100,000 workers, following mining with a death rate rate of 43 per 100,000 workers. Compared with an all-industry average death rate of nine per 100,000 workers, the death rate in agriculture is nearly five times higher. In fact, the actual death rate in agriculture is higher than the National Safety Council estimate because children under the age of 14 are not included, although they make up a sizable portion of agricultural work fatalities (Field and Tormoehlen, 1982; Murphy, 1985; Rivara, 1985; Tormoehlen, 1986). In addition to the fatalities, a much larger number of farmers and farm workers are injured each year with subsequent physical disabilities. According to the National Safety Council, in 1990, about 120,000 agricultural workers suffered disabling injuries as a result of farm work-related accidents.

Research shows that a great number of farm-related accidents resulted from a lack of safety consciousness when using farm equipment and performing other types of agricultural activities. Schumacher et al. (1989) conducted an investigation in conjunction with the Missouri Tractor-Testing Clinics on whether tractor owners/operators were using the Original Equipment Manufacturers (OEM) safety devices. The authors reported that approximately 50 percent of tractor power take-offs (PTOs) examined were not shielded, and only 18 percent of the tractors capable of locking brake pedals for road travel arrived at the clinics with the brakes locked. Farm tractor owners/operators tend to neglect the maintenance of OEM tractor safety devices as the age of the tractor increases. Sell and Field (1984) found that there was less than a 50 percent chance that tractor owners/operators would replace master shields after removing them. Huizinga and Murphy (1989) reported that about 70 percent of all tractor-related fatalities in Pennsylvania involved a rollover, and 81 percent of the tractors used on Pennsylvania farms were not equipped with rollover protective structures (ROPS)[1] . A recent Virginia farm accident survey (Zhao and Hetzel, 1991) revealed similar findings regarding the presence of ROPS on farm tractors. Therefore, educational programs and incentive interventions are necessary to reduce preventable farm accidents.

Agricultural activities with hazardous potentials are not much different from other high risk human activity. However, the hazards of agricultural work under variable conditions of exposure are more difficult to control. Unlike other industries, farm work generally involves a wide diversity of tasks and all ages of people. Activities are carried out under adverse environmental conditions such as rain, ice, snow, and mud. Agricultural workers, who may have inadequate training for the job, usually work with

[1] A rollover protective structure (ROPS) is a crushproof cab or frame which can protect the operator from serious injury if the tractor overturns, as may happen on unlevel terrain, during a sharp turn at high speed, or as a result of improperly attached implements, and other similar instances.

a minimum of supervision over an extended length of time while being subjected to stress, fatigue and pressure to complete work. Agricultural safety engineers have a formidable challenge in reducing the farm-related fatality and injury rates.

Accidents cost money and resources to the injured party, employers and the national economy as a whole. The costs of farm-related accidents include medical treatment, damage to properties, loss of working and leisure time, loss of income and production, loss of timeliness, replacement labor, and rehabilitation expenses. In recent years accident costs have increased dramatically. Farming most often is a self-employed occupation which excludes it from the workers' compensation law in many states. Once an accident occurs, the accident costs fall directly on the injured and the injured's family unless some form of insurance is provided. While insurance is available to cover farm workers, the premium may be relatively high and not all families elect to carry accident insurance. By current insurance practices, farm insurance premiums are approximately equal regardless of the injury risks of farm workers and the safety practices used by the enterprise. Due to the complexity of the insurance rating system and the unique characteristics of the farming profession, past research mainly focused on farm accident statistics. Existing agricultural safety literature does not relate farm accidents to farm insurance premiums. A risk-based framework for adjusting premiums would provide a scientific basis for input to farm insurance ratings. Adjustment of insurance premiums or related benefits could be used as an economic incentive to encourage adoption of safer farming practices so that preventable accidents and human suffering can be reduced. At the same time, insurance can provide farm workers and farm families with the necessary coverages should an accident occur. Moreover, the risk approach proposed in this study could also be useful in setting and evaluating agricultural education and research priorities.

Objectives

The overall objective of this study was to introduce a risk analysis approach for farm work-related injuries, and to develop a framework for defining safety research priorities and adjusting farm insurance premiums based upon risk analysis procedures. The specific objectives were as follows:

1. Identify variables associated with farm-related injuries which have significant impacts on the frequency and severity of injuries;
2. Examine and select the classification of injury severity;
3. Analyze and assess the costs of farm injuries;
4. Construct a framework to assess the expected costs of injuries of farm workers and thus to provide a scientific basis for setting safety research priorities and for input to a rational farm insurance rating system;
5. Using the framework, determine farm safety research priorities;
6. Conduct a sensitivity analysis to determine the impact of assumptions on the research priorities established.

Terminology

Every field of knowledge has its own specialized terminology. Terms that have very simple meanings in everyday usage often take on different and complicated connotations when applied in a specialized field. For the purpose of this study, several basic terms and concepts need to be defined and examined.

Hazard and Peril

A hazard is a condition that may create or increase the probability of a loss or an accident. It is not uncommon for the terms ***hazard*** and ***peril*** to be used interchangeably with each other and with ***risk***. However, to be precise, hazard is distinguished from risk and peril. A peril is a cause of a possible loss. It is possible for something to be both a peril and hazard, such as a fire.

Hazards associated with farm work include hazards of farm tractors and machinery; animals; hazards caused by molds, dust, gases and poor sanitation; hazards related to grain bins; exposure to silo gas; use of farm chemicals; hazards in traffic and on roads; farm fires; hazards resulting from weather, physical and emotional stress; extra riders; and hazards from use of electrical equipment (Schnieder, 1980).

The Concept of Risk

There are many definitions for risk depending upon the problem and application. In the insurance industry, risk often refers to an unfavorable condition in which there is a possibility of a deviation from a desired outcome that is expected or hoped for (Vaughan, 1988). For occupational safety and health professions, Lowrance's definition of risk has been widely adopted. "Risk is a measure of the probability and severity of harm to human health" (Lowrance, 1976). This interaction of susceptibility to harm and the magnitude of consequence is a prevailing component of most risk definitions. For the purpose of this study, risk is defined as the expected injury cost (EIC) index per farm worker per year. The EIC index combines the probability of injuries from a particular risk factor with the estimated costs of injuries, and thus provides a measure of both probability and severity of losses associated with farm-related injuries. The probability is an expression of the likelihood of the event occurring during a given time, while the severity of a loss denotes the magnitude of costs associated with a farm accident.

Accident and Injury

In the insurance industry, an accident is defined as an *event or occurrence which is unforeseen and unintended* (Vaughan, 1988). An injury is the *harm done* to the person's body by an external agent, such as a chemical, animal, equipment, machine, tool or other material, device or energy source. An accident may or may not result in an injury; a person may fall and not be injured. However, the words ***injury*** and ***accident*** are often taken to be synonymous, and refer to the same thing for many occupational safety and health professionals.

Farm Accidents

A farm-related accident refers to an event or occurrence that results in injury to a person(s), death, and/or damage to property. This study concentrated only on those farm accidents that resulted in injuries. Damage to property was not included because the economic consequences were not considered significant. To qualify as a farm accident, an injury during working activities must occur on farm property. Incidents occurring inside the farm house or on public roads and highways are excluded. To be a farm accident in this study, the injury required professional medical care or loss of one-half day or more of time from work or other normal activities. Professional medical care includes one or more contacts with a physician, a nurse, or another person acting under the physician's supervision. This definition of a farm accident is the same as that used in the National Safety Council standardized farm accident surveys conducted in the 1970s and early 1980s (Hoskin et al., 1988a).

Farm vs. Agriculture

A farm is defined by the U.S. Department of Commerce as any place selling (or normally selling) $1,000 or more of agricultural products in a year, while agriculture includes much more than farming. The U.S. Department of Commerce definition of agriculture, which is generally used by labor and safety professionals, includes such services as lawn care and veterinary medicine, but excludes agribusinesses, such as grain elevators and processing plants. The term ***agriculture***, used by the National Safety Council, includes not only production of crops and livestock (farming) and agricultural services, but also forestry (excluding logging), commercial fishing and hunting. According to the U.S. Bureau of the Census, a farm is a place consisting of ten or more acres of land and selling $50 or more of agricultural products annually, or consisting of less than ten acres and selling $250 or more of agricultural products annually. This definition of a farm was used in the National Safety Council standardized farm accident surveys (Hoskin et al., 1988a). The purpose of this dissertation study was to focus on farm work-related injuries. Therefore, the Census Bureau definition of farm was employed to define a farm. Recognizing geographical differences, the term farm in this study also includes ranches.

Chapter 2

Literature Review

A review of the literature revealed that virtually no work has been published on the relationships between farm-related injuries, injury costs, and insurance costs. Little research has been conducted regarding the costs of farm accidents or analyzing the variables involved or their associated risks. Most research work mainly focused on farm accident statistics. However, a review of related literature provided useful inputs to the methods and procedures developed in this study.

Causes of Farm Accidents

As discussed by Roberts (1979) and Roberts and Berry (1982), "job-related accidents can occur when one or more of the interacting elements (human, the work-related activity and environment) are significantly out of balance for the requirements of the job being done." The human factor is one of the key links "among these interacting elements and is responsible for accident production, either through unsafe behavior, error, oversight or through ill-chosen action in hazardous environments and situations." When studying fatal farm accidents in Wisconsin, Jensen (1980) found several primary human factors or errors which contributed to 50 of 69 accidents in 1977. These factors or errors included carelessness, poor judgement, lack of supervision, attitude, haste, fatigue, depression, intoxication, showing off, and stress.

Murphy (1986) discussed the fundamental tenets of human behavior with application to agricultural safety. There are four components of unsafe behavior -- operant conditioning, decision making, rare event and risk taking. The four components interact and enforce each other to the extent that the probability of an accident occurring is increased. For example, unrealistically low estimates attached to the hazard tend to result in a lower level of caution during the risk-taking activity. Thus, one focus of accident prevention is to educate and train farmers, farm workers, and their families in the safe use of agricultural chemicals and farm machinery, safety awareness of livestock operations, and the recognition of hazards involved in various agricultural activities.

In addition to human factors, hazardous environments and situations also contribute to the occurrence of farm accidents. An epidemiologic model was used by McKnight and Hetzel (1987) to study the causation of farm-related accidents. The model consists of three components -- the host (human), the agent, and the environment. The human factors constitute only one of the determinants of farm-related accidents. Characteristics of the human factors include age, gender, marital status, socioeconomic status, and physical condition. The agent in injury events is physical energy in its various forms (mechanical, chemical, thermal, radiation, and electrical). Environmental factors include variables in the biological, social and physical environment not included in the host and agent categories. Some examples of environmental factors listed in the McKnight and Hetzel study are:

- presence or absence of shields on PTOs
- farm family stress levels
- presence or absence of rollover protection structures (ROPS) on tractors
- overhead electrical lines near irrigation fields or the farmstead
- types of crops planted
- weather conditions

Each of these components (human, agent and environment) is interlinked to the other. The occurrence of an injury is usually the result of some interaction of these components.

Hazards of Farm Work

Accidents are invariably caused by the unsafe behavior of a farm worker and/or hazards of farm operations. The hazards usually contribute to the initiation of an accident. Therefore, when the emphasis is put on the human behavior in accident prevention, the important role of hazards, such as tractors without ROPS and unshielded power take-offs, should also be recognized. Accidents may be prevented or reduced through understanding the hazards associated with farm activities. To put the hazards of farm work into perspective, a brief review of farm-related accident statistics is useful.

Research indicates that fatal and permanently-disabling farm accidents typically involve tractors and other farm machines. From 1975 through 1981, 3,229 fatalities involving agricultural tractors and machinery were reported to the U.S. Consumer Product Safety Commission. Among these deaths, McKnight and Hetzel (1985) found that three-fourths were associated with farm tractors. Tractor overturns accounted for 47.6 percent of all tractor-related deaths. When studying farm work injuries in Pennsylvania, Huizinga and Murphy (1989) found that fewer than 20 percent of the tractors on Pennsylvania farms had rollover protection. Tractor fatality statistics in Pennsylvania showed that about 70 percent of all tractor related fatal accidents involved an overturn. Indiana data revealed that farm tractors and machines were involved in approximately 75 percent of all farm work deaths (Field et al., 1980). Farm tractors were also the most common factor in fatal accidents on Kentucky farms (Piercy and Stallones, 1984). During a period of 11 years from 1972 to 1982, farm tractors accounted for an average of 25 fatalities per year, and 59 percent of these fatalities resulted from overturns.

Beside farm tractors and machinery, animals also contribute to a great number of farm work-related accidents. Every year, thousands of farm injuries, including some deaths, occur as a result of animal-related accidents. A report by Hanford et al. (1982) disclosed that animals were the most common cause of farm accidents in a 31-state farm accident survey. Animals were involved with more total accidents and with more work-related accidents than any other operation and object on the farm. With all farm operations included, animal-related accidents accounted for 16.8 percent of the total farm-related injuries. While considering the beef and dairy operations, animals were involved in approximately one-fourth of the work injuries that occurred on these farms.

With increased use of agricultural chemicals, accidents resulting from exposure of chemicals and pesticides have gone up. Based on the 31-state farm accident survey (Hanford et al., 1982), agricultural chemicals contributed to about one percent of the total work injuries. Approximately one-half of the chemical-related injuries occurred while the victim was applying chemicals or filling the tank prior to application. Equipment failure accounted for 20 percent of the chemical injuries. In one of every five cases, the victim was reported as being unaware of the hazardous condition.

Although the potential for injury due to exposure to pesticides in concentrated form is smaller compared to the injuries involving farm tractors and machinery as well as animals, the long-term effect on the applicator's health from exposure to most agricultural chemicals may be significant. Research by Blair and his associates (Mueller, 1989) at the Environmental Epidemiological Branch of the National Cancer Institute revealed that certain agricultural exposures are positively correlated with deaths due to cancers of the prostate, brain, and lymphatic system. The other findings of the study by Blair et al. include:

- Grain-mill workers exposed to pesticides have higher than average risk for lymphatic and hematopoietic (blood-related) cancers.
- Lung cancer is high among commercial pesticide applicators. These people apply 25 percent of all pesticides in the United States.
- Farmers most at risk of getting leukemia are dairy farmers, growers using insecticides on large plantings of small grains, and young farmers in areas where heavy amounts of fertilizer are applied.
- There is an increased risk of getting leukemia and non-Hodgkin's lymphoma in agricultural countries with high levels of pesticide use.
- Multiple myeloma (tumors of the bone marrow) is more likely to occur among farmers who use the largest amounts of insecticides or who have large chicken-production operations, and particularly among operators under age 30.

- Applicators with 20 or more days per year of exposure to herbicides have six to eight times greater risk, over average farmers, of getting non-Hodgkin's lymphoma.

A study conducted by Doherty (1986) in Kansas showed a consistent result with the Blair et al. finding of a sixfold increase of of non-Hodgkin's lymphomas among farmers exposed to herbicides more than 20 days per years.

In addition to the accidents resulting from farm tractors and machines, animals, and use of chemicals, other significant types of serious farm accidents include fire, electrocution, falls, and asphyxiation, as well as entrapment and suffocation in grain bins.

Variables Influencing Occurrence of Farm Injuries

Studies found that many variables had statistically significant correlation to farm accident occurrence and the severity of injuries (Pfister and Hofmeister, 1969; Hoff, 1970; Schnieder et al., 1972; Stewart, 1977; Davis, 1983; Williams, 1983; Jester, 1985; Hoskin et al., 1988a). Among them were status of employment, age and gender of victim, experience level, operator training, type of agricultural operation, size of farm, hours of exposure to farm work, and work environmental conditions on the farm. The following review of literature is useful in identifying the variables which have a significant impact on the frequency and severity of farm-related injuries.

Studies in Michigan (Hofmeister and Pfister, 1968; Pfister and Hofmeister, 1969) revealed significantly higher rates of work injuries per million man hours for hired labor compared to farm family workers. Significant differences were observed in the distribution of injuries by age and gender of farm workers. Males, age five to 24, and 65 and over, experienced more injuries than other age groups. Work injury rates per million hours of exposure for male workers were higher than for female workers. No significant difference was found in injury rate per million hours of work exposure by farm size or type of agricultural operation.

A farm accident survey was conducted in Iowa during 1981 (Williams, 1983). A total of 2,578 farms from twenty counties participated, which represented more than two percent of all Iowa farms. The results of the survey indicated that frequency of farm injuries were correlated with farm size. Larger farms experienced the highest injury rate per farm, while smaller farms had the lowest injury rate per farm. By type of agricultural operation, beef farms had rates 50 percent higher than the average. Significant differences in injury rates were also observed among age groups. Younger farm workers under the age of 15 had a higher rate than the average of all age groups. The correlation between farm injury rates and age of farm workers was also reported by Jester (1985), based upon a Delaware farm survey. Work injury rates per 100 workers were the highest for the 15 to 24 year age group.

Hoff (1970) reported that accident rates per 100,000 workdays were higher for hired workers than for family members, based upon a survey conducted in New York. Male farm workers had higher rates than females. Injury rates per 100,000 workdays were also found to be correlated with age of farm workers, with workers under the age 15 having the highest rates of any age groups.

In a Nebraska farm accident survey which included about 7,000 persons on 1,764 farms, Schnieder et al. (1972) discovered significant differences in injury rates by age and gender of injured workers. All male age groups except 45 to 65 years experienced more injuries than expected based on hours of exposure. Males aged five to 14 had the highest injury rates. Significant difference were also found by type of agricultural operation. Beef farms had the highest work injury rates; and grain farms had the lowest rates. No significant differences were found in injury rates by farm size or employment status (hired versus family laborers).

A significant difference was found by Hanford et al. (1982) in the work injury distribution by age of farm workers, based on the analysis of the data from a 31-state farm accident survey. Persons aged 65 years or above were involved in approximately 19 percent of the fatal accidents reported. Nearly one-fourth of the fatal injuries occurred to the 25 to 44 age group. Approximately one-third of the fatal accidents involved persons in the 15 to 24 age group. Based on the same farm accident data base with additional four surveys included, Hoskin et al. (1988a) discovered that employment status was significantly related to the injury frequency. Hired farm workers had a significantly higher injury rate per million hours of work exposure than family members. The rate for family members was 19.5, while the rate for hired help was 21.7 injuries per million hours of farm work.

The influence of operator training on the accident rates was suggested in a Maryland farm accident survey (Stewart, 1977). The survey covered 1,231 farms in 22 of Maryland's 23 counties, which represented approximately eight percent of Maryland farms. A total of 175 accidents was reported from the survey. Of those accident victims, only one had been a 4-H member, one had had the hazardous occupation training program, and three had been in vocational agriculture.

Different types of agricultural operations will lead to differences in type and degree of exposure, and thus work-related injury experiences will vary from one farming enterprise to the next. The data collected from the National Safety Council standardized farm accident surveys was analyzed by dividing the data into five major commodity groups which included beef, dairy, grain, fruit and other operations. A report by Hanford et al. (1982) revealed that beef and dairy farms experienced higher than expected numbers of injuries.

Exposure to different hazardous environments will produce different likelihoods of an accident, different injuries and different losses. For example, tractors without a rollover protection structures (ROPS) have been shown by many researchers (Field et al., 1980; McKnight and Hetzel, 1985; Huizinga and Murphy, 1989; and Piercy and Stallones, 1984) as contributing the most to farm-related fatalities. On the other hand, hazards caused by gas or vapor were only involved in 0.1 percent of work-related injuries reported in the National Safety Council's 31-state farm accident survey summary (Hanford et al., 1982).

Classifications of Farm Injury Severity

The cost of an injury depends upon the severity of the injury and the type of accident. Several methods currently used to classify the injury severity levels were reviewed. The Abbreviated Injury Scale (AIS) and the Comprehensive Injury Scale (CIS) were first developed in 1972 by the American Medical Association Committee on Medical Aspects of Automotive Safety. The AIS was originally a ten-point scale and later condensed to a six-point scale in a 1974 revision. The latest revision of AIS was published in 1990 by the Association for the Advancement of Automotive Medicine (formerly the American Association for Automotive Medicine). The AIS was initially developed on the basis of clinical judgement. It is now presented in the form of a "dictionary" to minimize judgement so that the scale can be used by nonclinicians. The 1990 revision of AIS provides a measure of injury severity using a numerical scale of one to six. Code one in the AIS stands for minor injury, while code six denotes a maximum injury (a fatal accident). A study by the U.S. Department of Transportation (1983) utilized the AIS in analyzing the economic losses associated with motor-vehicle accidents. The costs of motor-vehicle accident-related injuries were evaluated by rating the severity of the injuries.

The Comprehensive Injury Scale (CIS) classifies injury severity based upon subjective clinical judgement. Five parameters are included in the CIS classification. These five parameters are: energy dissipation, threat to life, permanent impairment, treatment period, and incidence. For each parameter, there are five categories. For example, the categories for threat to life are: none, minor, moderate, severe, and maximum. The CIS scale is not continuous, and only provides a measure of injury severity on a nominal level.

Based upon the AIS ratings, Baker et al. (1974) and Baker and O'Neill (1976) developed an Injury Severity Score (ISS) to describe patients with multiple injuries and to evaluate emergency care. An individual's injuries were each assigned an AIS score from one to six depending on their severity; the three highest scores were squared and then added to give the ISS score. The ISS was not computed for anyone with an AIS 6 injury which have a probability of death equal to one. The ISS score provides a single measure of overall severity of the individual's injuries. No data was available for farm-related injuries on a national level by the AIS, CIS and ISS classifications.

Workers' compensation insurance pays workers' compensation benefits in additional to medical expenses, according to the following classifications of injury: (1) temporary partial disability, (2) temporary total disability, (3) permanent partial disability, (4) permanent total disability, and (5) death (Industrial Commission of Virginia, 1988). However, the majority of U.S. farms are family operated, and are excluded from the workers' compensation law.

The National Safety Council (Hanford et al., 1982) defined injury severity as slight, severe, permanent and fatal. A slight injury indicates minor cuts, sprains, and/or burns which require no or minor medical treatment; a severe injury involves a broken bone, cut ligament or tendon, sprained back, major burn, etc; a permanent injury includes amputation or loss of function of a body component; and a fatal injury is one that results in a death. This classification of injury severity was used in the national standardized farm accident surveys sponsored by the National Safety Council in the 1970s and early 1980s. Farm injury data classified by the National Safety Council definition of severity was available both on the state level and on a national scale.

Costs of Farm Accidents

Accidents cause pain, suffering and misery for the victims and grief for their families and friends. Furthermore, there is a great economic loss associated with accidents and injuries. The National Safety Council (1991) reported that accident costs in the United States totaled at least $173.8 billion in 1990, of which $63.8 billion resulted from work-related accidents. Pfister (1983) estimated the annual cost of agricultural work-related accidents at over $2.5 billion, based on the 1982 National Safety Council data.

The losses resulting from farm work-related accidents and injuries vary greatly depending upon a particular accident and injury. Based on the review of literature, the costs of farm accidents can be classified into two categories: major costs and minor costs. The probable major costs include medical treatment, damage to property, loss of income and productivity, loss of timeliness, replacement labor, rehabilitation expenses, modification to home and farm, costs of living supplements and fees for legal actions. The minor costs incurred as a result of farm-related accidents are relatively lower, compared to the major accident costs. The costs included in the minor category are such costs as emergency assistance, parking and mileage charges, funeral expenses in the case of fatal accidents, accident investigation and reporting, and others. The following is a discussion of various costs associated with farm-related accidents classified by the major and minor categories.

Probable Major Costs

Medical Treatment: The costs of medical treatment may include first aid; ambulance service; hospital emergency room treatment; hospital stay, both regular and intensive care; physician and surgeon charges; special laboratory tests, x-rays, prescribed drugs and other medicines, and other forms of medical care (Robbins, 1976).

Damage to properties: Possible losses as damage to properties resulting from farm accidents include damage to buildings, equipment, machinery and farm facilities as well as farm produce losses, such as standing crops, stored produce and livestock (Monk et al., 1986).

Loss of Income: Loss of income is another predominant element of the cost associated with farm accidents. The magnitude of income losses will depend upon factors such as amount of time lost from farm work, types of farm enterprises, and time of year accident or injury occurred. In the case of fatal accidents, loss of income could be estimated by considering the present value of the future annual earnings of the workers, had they survived and remained employment in farming (Monk et al., 1986).

Loss of Productivity: Productivity losses may be the largest cost incurred, especially if the accident results in a permanent disability and the victim was injured at a younger age. Productivity losses may be attributed to the inability to return to work, reduced efficiency of the injured person, and reduced efficiency of replacement laborers (Robbins, 1976). A report by Monk et al. (1986) indicated that the loss of productivity for an agricultural worker tends to vary seasonally and depending upon type and size of farm.

Loss of Timeliness:: For certain time-sensitive farming operations, such as cereal seeding and harvesting, a critical delay can reduce eventual output of the farm. Thus, the loss of timeliness in important operations should also be included as a part of cost resulting from an accident.

Replacement Labor: In addition to the actual wages paid, other replacement labor-associated costs include training new workers (Bird and German, 1966), loss of efficiency while an experienced worker is injured and replaced by a less skillful substitute (Naquin, 1975), and extra insurance for replacement workers. In some situations, it is even impossible to find suitable replacement labor.

Rehabilitation Expenses: Rehabilitation costs, when encountered, may be larger than the sum of all medical-related expenses. Rehabilitation expenses may include physical therapy, vocational capability assessment, special equipment or aids, and vocational training.

Modification to Home and Farm: In the cases of permanent disabling injury, the cost of modification to home and farm may occur. The extent of the cost will depend upon factors such as the type of permanent disabling injury suffered, the degree of the disability, and the type(s) of farm enterprises operated. In some cases, continuation of the farm operation may be impossible due to the injury (Tormoehlen and Field, 1984a).

Cost of Living Supplements: A pension for injured farm workers or dependents of those killed may result if workers' compensation or social security applies.

Fees for Legal Actions.: Many accidents that result in serious injury or permanent disability often require extended litigation. In some cases, liability claims may cost hundreds of thousands of dollars.

Minor Costs of Farm Accidents

Emergency Assistance Costs: The emergency assistance costs may include such expenses as police assistance, fire department assistance, and emergency rescue squad assistance as well as time of personnel involved in rescue (Tormoehlen and Field, 1984a).

Mileage and Parking Charges: Mileage and parking costs commonly incurred by the victim and his or her immediate family are for hospital visits, rehabilitation center visits, doctor office visits, and trips to obtain medical supplies.

Funeral Expenses: In the case of fatalities, funeral expenses should also be included in the expected costs of an accident.

Accident Investigation and Reporting: Costs incurred may include those of accident investigation and reporting. These costs would vary depending upon time personnel spent investigating the accident, hourly rates of people involved and paper work generated by the accident.

Other Costs: In addition to the injured person, family members and hired laborers may experience income-related losses associated with the farm accident. Such losses are time spent assisting the injured person at the time of an accident, time spent visiting the injured person during the hospital stay, and time lost from off-farm jobs and other nonproductive activities.

The aforementioned major and minor cost categories are only a partial list of the costs that may be incurred as the result of farm-related accidents. Thygerson (1977) compared accident costs to an iceberg -- only a small portion which appears above water can be seen and actually measured. The indirect and hidden costs are analogous to the part of an iceberg below the water surface. The cost categories encountered in any particular accident will depend upon the type of accident, injury suffered, farm size, and type(s) of farm enterprises. The diversity of costs makes it very difficult to identify every single category encountered as the result of a farm-related accident.

Estimate of Injury Costs

Studies of farm accident costs were only found in a few reports. Information about the costs of farm-related injuries was collected in the standardized farm accident surveys conducted in 31 states (four states repeated the survey). However, the data was only available in about half of the reported accident cases regarding the consequences of injuries in terms of medical treatments, lost workdays, and other costs (Hoskin et al., 1988a and 1988b). Of those cases reporting medical cost information, approximately 75 percent had costs less than $100; and about 11 percent exceeded $500 in medical costs. In almost 90 percent of the specified cases, there was no expenditure for replacement labor. Property damage costs were associated with only approximately 15 percent of the cases. No other related injury costs were reported in the surveys. The data has limited value because it was collected over a time period of many years and lacked completeness and accuracy.

Tormoehlen and Field (1984a and 1984b) investigated the economic impact of agricultural related injuries on the farm family or rural community. They identified the factors, both direct and indirect, as well as the magnitude of the economic losses associated with permanent disabilities resulting from farm-related accidents (1984a). A computer model was developed (1984b) to include the cost factors and project the estimated costs associated with the farm-related permanent disabilities. Major components of the model include Consumer Price Index (CPI) data, personal data, body part injured, types of injuries, injury severity level, types of accident/injury-related costs, and default values. The study was limited to a few selected cases of farm-related permanent disabilities.

Costs of farm accidents were estimated by Monk et al. (1986) in Great Britain. The accident information was obtained on all 56 fatal accidents and on 791 non-fatal accidents reported to the Health and Safety Executive during the period from July 1, 1981 to June 30, 1982. Visits were also made to 805 farms to obtain unreported accident information. Among these accidents, about 60 percent involved personal injury. Half of the accidents involved tractors and field machinery. The methods of estimating the farm accident costs were partly based on the techniques developed in other sectors, notably for industrial and highway accidents. Modifications were made to suit the special features of farming, such as the seasonality of farm work and the preponderance of self-employed persons and small family businesses.

The costs related to farm accidents have not been quantified, most probably due to incomplete data. Unlike mining, construction, and other industrial accidents that are investigated and documented under federal and state regulations, and about which ongoing statistics are kept by government agencies, farm accidents are generally not investigated, not documented, and typically not included in government statistics. A clear and detailed picture of costs for farm-related injuries and fatalities is not provided by existing literature. However, there is no reason for the farm-related injury costs to be less than those for other types of injuries. Therefore, a brief review of literature on the injury cost studies for other industries would provide some input to assess the costs associated with farm-related injuries.

According to the National Safety Council estimates (1991), the average cost of a work-related disabling injury over all industries is about $18,000. The cost includes medical expenses, loss of wages, insurance administration cost and uninsured costs, but it excludes property damage. An average work death costs more than $600,000, due primarily to lost earnings. The intrinsic value of life is certainly beyond dollar figures. As a matter of fact, the costs for a permanent total disability are normally higher than a fatality. Sheridan (1979) discussed the costs of an accident based upon estimations from Alcoa Corporation, a self-insurer. Alcoa's experience suggested that the cost for a fatality would be $100,000, while each permanent total disability would cost $200,000 based on 1979 dollars. The costs of fatal injuries included: life insurance, family insurance continuation, surviving spouse insurance, pension payment, and replacement employee training. The costs for a permanent disability included disability pension plus supplemental costs such as replacement, rehabilitation and insurance.

Two methods to estimate the costs of injuries were discussed in the report to the U.S. Congress, *Cost of Injury in the United States* (Rice et al., 1989). The two methods are "human capital" approach and "willingness to pay" approach. The human capital approach measures the injury costs based on productivity lost or reduced due to injury. According to *Cost of Injury in the United States*, on average, each injury death resulted in 36 life years lost and a productivity loss of over $300,000 expressed in 1985 dollars. The human capital approach measures the injury costs at market values. For example, for injuries causing a person's death, the method calculates the amount of income that person would have otherwise earned over his or her lifetime. The costs for pain, suffering, and reduced quality of life are not included. Thus the human capital method tends to undervalue the lives of people who are victims of accidents.

The other approach estimates the costs of injuries based upon an individual's or society's "willingness to pay." Human life is valued "according to the amount individuals are willing to pay for a change that reduces the probability of illness or death. This approach assumes an individual perspective and incorporates all aspects of well-being, including labor and non-labor income, and value of leisure, pain, and suffering", according to the authors of *Cost of Injury in the United States.* A result of 29 studies (Rice et al., 1989) revealed that the average cost of a fatal injury was $1.95 million (1985 dollars) estimated by using the "willingness to pay" approach. For nonfatal injuries, the averages for four severity classes (moderate, serious, severe, and critical) range from 30 thousand to 1.5 million dollars. The willingness-to-pay estimates are four and one-half to six times higher than those calculated by the human capital approach.

Risk Assessment Analysis

Risk analysis for agricultural work activities was first reported in the literature by Roberts (1979). Roberts (1979) and Roberts and Berry (1982) proposed a risk assessment method for agricultural jobs. Total risk was used to quantify the hazard potentials of agricultural tasks for individual farm workers. Risk measurement included job description, job hazard rating and job exposure for individual farm workers. The total risk for a specific farm worker was assessed on an annual basis by summing the products of job exposure times the job hazard ratings for the worker. The job hazard ratings were determined in the opinion of the assessor, and compared with accident statistics collected from the same work unit or similar agricultural enterprises. The overall approach consisted of the following four steps:

1. Assess risk for each task and assigned worker;
2. Compare assessed risks to pertinent accident statistics;

3. Re-evaluate jobs in terms of short-term and long-term risks and prioritize according to the "vital few", i.e. the few accident types which account for the largest percentage of injury cost;
4. Determine potential action for worker protection.

When combined with the analysis of relevant agricultural accident statistics, Roberts (1979) and Roberts and Berry (1982) proposed that the risk assessment method be used to provide a rational basis for determining corrective actions to reduce and eliminate farm-related accidents and injuries.

McKnight and Hetzel (1987) discussed several common methods for measuring and expressing risks of farm injuries and fatalities. These methods include incident rate, prevalence rate, mortality rate, morbidity rate, case fatality rate, and relative risk. By the McKnight and Hetzel definitions, the incidence rate estimates the occurrence of new injury cases in a particular population per unit of time, while the prevalence rate measures the likelihood of all existing cases of injury at a given point in time (day, week or month) within a population regardless of when the injury status began. The mortality rate (death rate) is a measure of frequency of new death cases due to particular causes, per unit of time, in a given population. In contrast, the morbidity rate is "an incidence rate that measures the occurrence of specific nonfatal episodes of injury per unit of time, within a given population. The emphasis of the morbidity rate is on sickness/impairment from injury, rather than on death." The case fatality rate measures the lethality of injury, i.e. the proportion of persons acquiring a specific injury who die from that episode. Finally, the relative risk estimates the excess risk, and is expressed as "the ratio of two incidence rates where one group (the numerator) was exposed to a specific risk factor and the other group (the denominator) was not exposed to the risk factor. Relative risk provides a measure of excess risk associated with a specific risk factor. For a relative risk greater than one, the risk factor is associated with an increased probability of developing the particular injury or accident. If the relative risk is less than one, the exposure is linked to a protective effect of the risk factor."

A quantitative risk assessment model was developed by Madsen (1985). The model related product reliability to its safety, and was used to calculate risk with potential system or part failures. He studied the factors affecting reliability and associated risk when failures could lead to accidents. The analysis was, however, limited to the pre-production of products.

Freeman et al. (1990) developed a knowledge-based system, Farm Accident Risk Management & Data Acquisition sYstem (FARMDAY), to acquire injury information and identify hazards on farms and ranches in the state of Texas. Risk was expressed as risk factors in the study. The system calculated the user's risk factors in the major areas of agricultural fatalities, based on the probability of a fatal accident occurring for a particular activity as well as the exposure level of the worker. An expert's experience in the farm safety area was used to develop the questions related to the risk factor of farm fatalities in six major categories of agricultural activities. These categories were: tractor/machinery, drownings, firearms, fires/burn/explosions, electric shock, and animals. The risk factor in each of the six categories is initially zero. The factor is then increased or left unchanged depending on how the user answers the questions. When a risk factor has been calculated for each of the six categories, they are then combined into an overall farm risk factor, using the percentages of each category related to the total database. While collecting valuable agricultural injury data from the user, the system also provided the user with educational information related to high risk activities. Since only fatality data was used, the loss resulting from an accident was considered as a constant in calculating the risk factors. In fact, the loss from a fatal accident would depend upon the victim's education and experience, the victim's age at the time of the accident, and other factors. In addition, the system was based on Texas agricultural fatalities and limited to selected agricultural activities.

Farm Injury Data Sources

Reliable accident data is vital for the risk assessment analysis of farm-related injuries. Identifying sound data sources is a key link for this study. Farm accident information is available either on the state level or on a national scale. Common sources of fatality information on the state level for farm workers are death certificates, newspaper clipping as well as personal contact with agricultural extension agents, and the family of the deceased. Using these sources, fatal farm accidents have been tracked in many states (Baker and Stuckey, 1973; Wardle and Hull, 1975; Jepsen, 1981; Schnieder, 1983; Krantz, 1985; Trus and Schultz, 1985; Valco, 1989; Becker, 1990; Murphy, 1985 and 1990). However, the accuracy and completeness of data as well as the problems of classification of deaths have been discussed by Murphy (1989). He indicated that the death certificate was not adequate for counting and classifying agricultural fatalities.

Non-fatal injury information at the state level has been collected by various methods. These methods include workers' compensation records, clinic and/or physician and hospital records, and farm accident surveys. Workers' compensation data has been analyzed in some states (New York State Department of Labor, 1972; California Department of Industrial Relations, 1978; Becker, 1990). However, the data collected by this method has limited coverage and could not represent the broader farm accident experience, since family-farm operations and farms with ten or fewer employees are typically except from workers' compensation laws.

Injuries requiring medical treatment have been tracked in some states through reports from physicians, clinics and hospitals (Peterson, 1973; Cogbill and Busch, 1985; Stueland et al., 1990a and 1990b). Due to the lack of success in collecting information through these sources, an accident survey is still used as one major source for gathering the farm-related injury information.

Statewide farm accident survey statistics were reported by a number of states (Stuckey and Pugh, 1973; Bubolz et al., 1977; Field and Bailey, 1977; Murphy, 1977; Stewart, 1977; Bean, 1979; Fanning, 1982; Davis, 1983). Most of the reported injury data was collected during the 1970s and was later pooled in national·farm accident survey summaries (Hoskin et al., 1988a, 1988b and 1988c). Huizinga and Murphy (1987) developed a personalized mail survey procedure to collect the agricultural injury data. The surveys using the personalized-mail procedure have been conducted in several states including Pennsylvania, Oregon and Virginia, and the summaries from these three states were reported by Huizinga and Murphy (1989), Cavaletto (1989) and Zhao and Hetzel (1991), respectively. However, the data gathered using the mail survey approach only contains very general information regarding farm-related accidents, such as the number of accidents occurring on farms, an accident rate per farm and general description about each accident. No information was provided on the hours of exposure to farm work by gender and age of farm workers as well as types of agricultural operations. Moreover, underreporting and incomplete data were also found with the mail survey approach (Zhao and Hetzel, 1991).

The national data bases are very limited in number. One source of national farm fatality data is the National Center for Health Statistics (NCHS), U.S. Department of Health, Education and Welfare. Information is available from NCHS for all deaths in the U.S. tabulated by location of death, with farms as one of the locations. Based on the NCHS data, Fritsch (1976) analyzed the occupational and nonoccupational fatalities of farmers and hired farm workers for the years 1969-1971. The results were reported in the Agricultural Economic Report No. 356 of the National Economics Analysis Division, Economics Research Service, U.S. Department of Agriculture. The NCHS data base was investigated again by Fritsch and Zimmer (1980) for the U.S. farm accident fatalities from 1970 to 1976, and the results were summarized in the Agricultural Information Bulletin No. 434, U.S. Department of Agriculture. The NCHS data covered only fatalities and provided no information on other farm-related injuries. Moreover, the fatality data compiled by the NCHS was based upon coroners' reports which provided no information on whether the fatality was work-related or not.

Another source of information for farm fatality data is the consumer product-related death certificate data compiled by the U.S. Consumer Product Safety Commission (CPSC). The CPSC collects consumer product-related death certificates from the vital statistics bureaus of the fifty states, the District of Columbia, New York City, Puerto Rico, and Virgin Islands. Large numbers of observations were provided in the CPSC data which covers a wide range of agricultural machinery incidents over many years. Utilizing the CPSC data, McKnight (1984) analyzed farm machine-related fatalities from 1975 through 1981. A total of 3,229 deaths were identified during the period involving over 35 agricultural products, primarily farm machinery and farm tractors. Common farm machines included auger-elevators, cornpickers, manure spreaders and power take-offs. Tractors were associated with about three-fourths of the fatal accidents; one-half of these occurred when the tractor overturned.

Workers' compensation data for agricultural workers is another source of information. Burkart et al. (1976) identified 129,000 cases of agricultural injuries and illness based upon the workers' compensation data from eight states. The authors found that the workers' compensation data was subjected to limitations on its adequateness and accuracy because of incomplete coverage, lack of record detail, coding incompatibility, underreporting, and reporting error.

One other major source of farm accident information on the national level is national agricultural injury surveys. The National Safety Council (NSC) and the U.S. Department of Agriculture sponsored a Standardized Farm/Ranch Accident Survey starting 1968 (Hoskin and Miller, 1979). Efforts were made to gather farm accident data on the national level. Every year, about ten states participated in the survey program. The surveys used standardized accident forms, definitions, and sampling techniques and procedures. The data collected from each of these survey states was pooled to form a national farm accident data base. By 1979, 18 states had contributed to the pooled data base and the data were analyzed and summarized in a report by Hanford et al (1979). One other report was also published in 1979 when a new pool of data from 21 states with over 24,700 farms was analyzed and summarized (Hoskin and Miller, 1979). The collected data from these 21 states covered a total of 126,051 farm workers, and 4,176 injuries and illness were recorded. The emphasis of the 21-state summary was given to the animal-related injuries.

By 1981, the standardized farm accident survey sponsored by the National Safety Council had been conducted in 31 states. The analysis of the national pool of data from those states was completed and published by Hanford et al. (1982). The data base consisted of 160,789 persons on 31,398 farms and ranches, representing two percent of all farms and ranches in those states. A total of 4,612 injuries was reported. Work-related injuries accounted for over three-fourths of the total injuries.

Hoskin et al. analyzed and summarized the standardized farm survey data again in 1988 with additional survey data included. The summarized results were presented in *Occupational Injuries in Agriculture: A 35-State Summary*[2] under NOISH contract No. DSR-87-0942 (Hoskin et al., 1988a). In conjunction with this report, two related analyses of the 35-state farm survey data were performed and reported. One was an in-depth analysis of the survey data on tractor-related work injuries (Hoskin et al., 1988b). The other detailed the agricultural machinery-related injuries (Hoskin et al., 1988c).

The 35-state farm survey data provided a rich source of information on farm-related injuries because of the breadth of its coverage. The data recorded the injury experience of 127,224 family members and 57,426 full- and part-time hired farm workers on 37,293 farms in 31 states. More than 5,753 injuries were described in the data base, from relatively minor recreational injuries occurring to children living on farms to permanently crippling or fatal occupational injuries. Of the total injuries, 4,105 or 71 percent were work-related. The 35-state farm accident survey data also includes the information regarding hours of work exposures and injuries by employment status, gender and age of farm workers, as well as injuries by the type of agricultural operations.

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[2] Surveys were actually conducted in 31 states. Four states repeated the survey.

Chapter 3

Methods and Procedures

To utilize risk assessment methodologies for farm related injuries, risk must be defined. As discussed in the review of literature section, risk can be defined in many different ways depending upon the problem and application. In this study, risk is defined as the Expected Injury Cost (EIC) index per farm worker per year. The EIC index combines the probability of injuries from a particular risk factor with the estimated costs of injuries. Thus, it provides a measure of both likelihood and severity of losses associated with farm related injuries. The EIC index was computed based upon the risk analysis of farm injuries among the risk factors which have significant impacts on frequency and severity of farm work-related injuries. What is of interest are relative risks among particular risk factors, say, the likelihood of injury occurring to a dairy farm worker verses a grain farmer, or the likelihood of a 20 year old farm worker being injured compared with a farm worker of age 45, and so forth. Hence, the concept of relative risk was used in this study. The EIC index could provide a basis for setting agricultural safety education and research priorities. In addition, by combining the relative risk index of individual workers and the number of employees as well as different agricultural operations conducted on a farm, a composite risk factor would be derived to provide input to a rational rating system for farm insurance.

There are four major steps in the risk assessment analysis of farm injuries. They are: (1) determination of risk factors, (2) injury severity classification, (3) cost estimation, and (4) risk characterization. The overall approach used for reaching the objectives of this research effort was to combine the analysis of injury data with the judgement and opinions from farm safety experts.

Determination of Risk Factors

Risk factors are those variables associated with farm related injuries that influence the frequency rates and severity of injuries. By reviewing the literature and consulting with farm safety experts, six variables were found to be significantly correlated with the frequency and severity of farm-related injuries, and were included as risk factors in this study. The risk factors determined were employment status, age of farm worker, gender of farm worker, hours of exposure to farm work, the type of agricultural operation, and hazardous conditions around the farm.

There is no agreement among various studies concerning the influence of farm size on work injury rates. Schnieder et al. (1972) found no significant difference in injury rates by size of farm, based on a Nebraska farm accident survey. Some other studies (Davis, 1983; Williams, 1983) showed correlation between work-related injury rates and size of farm. Large farms appeared to have a higher injury rate per farm than small farms. This result would be expected because of the greater number of hired help and the larger amount of exposure hours to farm work on the large farms. Since the employment status and hours of work exposure have already been considered in the analysis of farm injuries, size of farm was not included as a significant risk factor in the study. Other variables, such as farmers' experience levels or years involved in farming, and operator training, might also have an impact on the occurrence of farm-related injuries. However, they were not included in this analysis because it is difficult to quantify their effect on the occurrence of injuries.

Except for hazardous conditions around the farm and/or ranch, the risk factors included in the study are mostly self-explanatory. Exposure to various hazardous environments will produce a different likelihood of an accident, different injuries and different injury losses. There are many hazards associated with farm work as discussed in the review of literature. However, tractors without rollover protective structures (ROPS) require special attention. Studies indicate that tractors and farm machinery are the leading cause of fatalities on U.S. farms (Huizinga and Murphy, 1989; Hetzel et al., 1991). Among tractor and machinery related fatal accidents, tractor overturn was the most common incident (McKnight and Hetzel, 1984). The National Safety Council (1991) estimated that 52 percent of the tractor-related fatalities occurring on U.S. farms in 1990 involved overturns. Almost all tractor-rollover fatalities could be prevented if ROPS were present and seat belts were used effectively. Strong evidence of the impact of ROPS applications for eliminating tractor rollover death has been established in Sweden (Springfeldt and Thorsen, 1987). The risk posed by tractors without ROPS is very evident.

The American Society of Agricultural Engineering (ASAE) in 1967 established the first performance standard and test procedures of ROPS for agricultural tractors

(ASAE Standard: ASAE S383.1). The Occupational Safety and Health Administration (OSHA) imposed a safety regulation in 1976 which requires ROPS to be installed on all tractors used by employees. However, the OSHA rule does not apply to family farm operations, nor to farms with ten or fewer employees (excluding family members). Together, these two exceptions eliminated the desire to comply with this safety regulation for the majority of the agricultural operations in the United States. Consequently, most farmers were given an option of purchasing tractors with or without rollover protection from 1976 to 1985. A study of farm-tractor fatalities in Wisconsin (Karlson and Noren, 1979) indicated the lack of effectiveness of the voluntary safety standards. Recent farm accident surveys conducted in Pennsylvania and Virginia revealed that the majority of tractors used on farms in these states are not equipped with ROPS (Huizinga and Murphy, 1990; Zhao and Hetzel, 1991). Similar situations may be prevalent throughout the country. Since tractors are widely used in agricultural operations and many farm injuries and fatalities are tractor related, the hazards of tractors without ROPS was given special attention in this research.

Injury Severity Classification

Injury severity classification is an important link in the risk assessment analysis of farm injuries since the costs associated with an injury depend upon its severity. Considering the methods examined for classifying the severity levels of injuries, no data was available for farm-related injuries by the Abbreviated Injury Scale (AIS), Comprehensive Injury Scale (CIS) or Injury Severity Score (ISS) classifications. The workers' compensation classification of injuries is not suitable for this research because the majority of U.S. farms are family operated, and are excluded from the workers' compensation law. On the other hand, farm injury data defined by the National Safety Council classification was available at the state and national levels. Hence, the injury severity levels defined by the National Safety Council (Hanford et al., 1982) were adopted in this study.

Cost Estimation

Cost estimation involves analyzing and assessing the costs associated with farm injuries. The losses incurred as a result of farm-related accidents vary greatly depending upon the particular accident. As discussed in the review of literature, major costs associated with farm-related accidents include: medical treatment, losses of income and productivity, loss of timeliness, replacement labor, rehabilitation expenses, home and farm modification in case of permanent disability injury, cost of living supplements for a fatal accident if workers' compensation or social security applies, and fees for legal actions that may follow. Damage to properties was not included since the economic consequences were not considered significant, compared to medical and other costs resulting from work-related accidents on farms. The 35-state farm survey data indicated that approximately 84 percent of the reported cases involved no property damage costs (Hoskin et al., 1988b). The diversity of costs involved make it impossible to quantify the exact costs of farm-related injuries. However, the major expected costs associated with certain levels of injury severity can be estimated.

Representative data on the costs of farm work-related injuries is not available. This study based the expected costs for different levels of injury severity on assumptions: $50 for a slight injury, $1,000 for each severe injury, two-million dollars for a permanent injury, and 1.5 million dollars for each fatality. The following factors were taken into consideration for generating these costs:

- information on the injury costs from other industries,
- "human capital" approach for the estimate of injury costs,
- an individual's "willingness to pay" for a work-related injury or fatality,
- limited and incomplete cost data from the standardized farm accident surveys conducted in the 1970's and early 1980s.

It should be pointed out that the results of the EIC indices for farm workers and activities would vary depending upon these injury costs. However, with additional research efforts on farm safety, more complete and reliable information on the costs of farm work-related injuries will become available, and then the expected injury costs will also become more reliable.

Risk Characterization

Risk characterization identifies the likelihood of an injury resulting from a particular risk factor, and then combines the probability with the estimated injury costs to produce the EIC index for a particular farm worker. To obtain the EIC index, the probability of an injury due to exposure to farm work was first identified and then multiplied by the estimated injury costs to derive the expected injury costs. Then the expected injury costs were averaged for each element within each risk factor, such as different age groups and agricultural operations. The EIC index was calculated by dividing the expected cost from a particular element by the average value of expected costs within the risk factor category.

The detailed calculation procedures of the EIC index for farm workers and activities can be formulated as follows:

1. Identify the frequencies of injuries classified by severity resulting from a particular risk factor, based upon the available data sources.

2. Compute the total expected injury cost for each element of the risk factor by summing the products of the frequency of injuries and the estimated cost for each injury severity level. Therefore, the total expected injury costs for the jth element, TC_j, within a risk factor can be expressed by the equation:

$$TC_j = \sum_{i=1}^{4} f_i \times C_i \qquad (3.1)$$

where

f_1 = frequency of slight injuries due to the jth element of a risk factor,

C_1 = estimated cost of a slight injury,

f_2 = frequency of severe injuries due to the jth element of a risk factor,

C_2 = estimated cost of a severe injury,

f_3 = frequency of permanent disability injuries due to the jth element of a risk factor,

C_3 = estimated cost for a permanent disability injury,

f_4 = frequency of fatal injuries due to the jth element of a risk factor,

C_4 = estimated cost for each fatality.

3. Estimate the total expected injury cost per million hours of work exposure for the jth element, CR_j, by dividing the total expected injury cost by the exposure time (million hours):

$$CR_j = \frac{TC_j}{t_j} \tag{3.2}$$

where

t_j = exposure time to farm work, expressed as million hours.

4. Obtain the weighted average expected injury cost rate, WR, for the risk factor considered using the equation given below:

$$WR = \sum_{j=l}^{n} CR_j \times w_j \tag{3.3}$$

where

w_j = weight factor of the jth element of the risk factor.

n = number of elements within the risk factor considered.

5. Calculate the EIC index for the jth element of the risk factor using Equation (3.4):

$$\text{EIC index} = \frac{CR_j}{WR} \tag{3.4}$$

The EIC index provides a measure of relative risks within each risk factor, such as a hired farm worker versus a family member, or a dairy farmer versus a grain farmer.

An EIC index greater than one indicates a higher probability of injury with a greater loss from a particular risk factor, and should therefore be given more attention to prevent injuries from occurring.

Data Sources

A risk assessment for farm-related injuries must be based upon available data sources. Farm accident statistics are available from many sources, both statewide and on a national level. However, a publication, *Occupational Injuries in Agriculture: A 35-State Summary* (Hoskin et al., 1988a) found to be the best source available at the present time. Hence this publication was used as the main source of information for risk assessment of injuries resulted to farm work. The following is a brief summary of the results from the 35-state farm accident surveys.

Hoskin et al. (1988a) included the results of 35 surveys conducted in 31 different states (four states repeated the survey). During the survey, information on 4,105 work-related injuries was recorded from a total of 37,293 farms. Of the farms surveyed, 28.9 percent were corn, sorghum, and small grain operations, 19.2 percent produced beef, and 17.6 percent were dairy farms. The remaining 34.3 percent of the farms represented a wide variety of agricultural operations.

The survey covered a farm population of 184,650, including both family members and full- and part-time farm workers. Among them, 127,224 or 68.9 percent were family members living and working on the farm, and 57,426 or 31.1 percent were hired labor. Male farm workers made up 55.9 percent of the family members and 80.5 percent of the hired workers. Females accounted for 44.1 percent of the family members and 19.5 percent of the hired employees.

The hours of exposure to farm work reported in the surveys totaled 203.6 million hours. Family members worked 162.5 million hours, accounting for 79.8 percent of the total work hours reported in the surveys. The hours of exposure to farm work for hired workers was reported as 41.1 million hours which accounted for 20.2 percent of the total work hours. Male family members recorded 121.5 million hours of farm work and male hired employees worked 37.1 million hours. The work exposure for female family members totaled 40.9 million hours, while female hired workers reported to have only 4.1 million hours of work exposure.

Injury information corresponded closely to the work exposure distribution. Family members experienced 3,202 or 78.0 percent of the total 4,105 work-related injuries, while hired workers had 903 work injuries which accounted for 22.0 percent of the total injuries. Males experienced 83.1 percent of the family member injuries and 91.8 percent of the hired labor injuries.

Hired workers had significantly higher injury rates per million hours of farm work than family members ($\chi^2 = 7.78$, df = 1, $p < 0.01$). Combining males and females, the injury rate for family members was 19.5, while the rate for hired labor was 21.7 injuries per million hours of exposure to farm work. The overall rate for all farm workers was calculated to be 20.0 injuries per million hours of work exposure. The injury rates per million work hours by gender of workers indicated that male farm workers had much higher rates than females. The injury rate for male family members was 21.7 injuries per million hours of work exposure, while the rate for female family members was 13.1. For hired farm workers, males had a rate of 22.2 injuries per million work hours while females experienced 17.4 injuries per million hours of farm work.

Table 3.1 lists the number of family members and hired labor by gender of farm workers. The information on the injuries experienced by the groups, hours of farm work and injury rates per million hours of work exposure for each group is also illustrated in Table 3.1.

Work-related injury severity by age and employment status of worker is given in Table 3.2. The distribution of work exposure by age for family members differed from that of hired labor as shown in Table 3.2. Age was significantly correlated with injury experience for both family members and hired labor. Hours of work exposure and injury experience were not listed for the age group of five to 14 years for hired workers, because people in this age group cannot be employed for almost all types of farm work and thus were not included in the risk analysis of this study. The injuries per age group in Table 3.2 were based upon exposure to all hazards involved in farming activities. Hoskin et al. (1988a) did not provide information regarding the frequency of injuries by age of worker due to a specific hazard.

Work exposure and injuries by type of agricultural operation is presented in Table 3.3. Beef, dairy and fruit farms had a higher than expected number of injuries. Due to missing data, the injury rates by type of agricultural operation shown in Table 3.3 are not equal to the numbers of injuries divided by hours of work exposure. Table 3.4 gives the frequency of work injuries by severity and type of agricultural operation.

It should be pointed out that the data presented in Table 3.1 through 3.4 may be slightly different from the original data since the author did not have direct access to

Table 3.1. Number of Farm Workers and Distribution of Work Hours, Work Injuries, and Injury Rates by Employment Status and Gender of Worker

Status	Number of Persons	Injuries	Work Hours (million)	Injury Rate* (per million hours)
Family members				
Male	71,118	2,660	121.5	21.7
Female	56,106	542	40.9	13.1
Total	127,224	3,202	162.4	19.5
Hired workers				
Male	46,228	829	37.1	22.2
Female	11,198	74	4.1	17.4
Total	57,426	903	41.2	21.7
Total	184,650	4,105	203.6	20.0

* The injury rates are not equal to the number of injuries divided by hours of work exposure due to missing data.

Source: Occupational Injuries in Agriculture: A 35-state Summary (Hoskin et al., 1988a).

Table 3.2. Work Injury Severity by Age and Employment Status of Worker

Age Group	Hours of Exposure (million)	Injury Severity*			
		Slight	Severe	Permanent	Fatal
Family members					
5-14	8.13	62	151	3	2
15-24	23.91	170	356	11	2
25-44	56.63	318	727	22	4
45-64	64.02	299	792	27	8
65 or above	9.78	48	132	7	3
Hired workers					
15-24	12.97	149	206	3	3
25-44	17.72	126	204	4	5
45-64	8.25	57	88	2	0
65 or above	1.49	9	18	1	0

* Unknown severity of injuries are not included.

Source: Occupational Injuries in Agriculture: A 35-state Summary (Hoskin et al., 1988a).

Table 3.3. Work Injuries, Hours of Exposure, and Injury Rates by Type of Agricultural Operation

Agricultural Operation	Injuries	Hours of Exposure (million)	Injury Rate* (per million hours)
Beef	542	21.63	23.3
Dairy	932	38.86	22.3
Grain	776	35.90	20.1
Fruit	168	6.65	23.5
Other	1,687	100.56	15.6
Total	4,105	203.60	20.0

* The injury rates are not equal to the number of injuries divided by hours of work exposure due to missing data.

Source: Occupational Injuries in Agriculture: A 35-state Summary (Hoskin et al., 1988a).

Table 3.4. Severity of Work-related Injuries by Type of Agricultural Operation

Operation	Injury Severity*			
	Slight	Severe	Permanent	Fatal
Beef	134	390	5	3
Dairy	252	642	26	3
Grain	218	515	19	5
Fruit	68	94	0	0
Other	477	1,126	41	13

* Unknown severity of injuries are not included.

Source: Occupational Injuries in Agriculture: A 35-state Summary (Hoskin et al., 1988a).

the original data base. A few figures were recalculated from the original reference (Hoskin et al., 1988a).

To analyze the relative risk of injuries due to the specific hazards of tractors without ROPS versus those equipped with ROPS, this study utilized the data concerning agricultural tractor and machinery fatalities from 1975 through 1981 (McKnight, 1984). During the seven year period, a total of 2,439 fatalities were identified as farm tractor related. Among those 2,439 cases, 108 occurred to children under age of five. The purpose of this dissertation study was to concentrate on farm work-related injuries. Therefore, the fatalities which occurred to farm children under age five were excluded in the analysis because they were not considered as work-related. For the remaining 2,331 fatalities, tractor overturns accounted for 1,159 cases, or approximately 50 percent of the total tractor-related fatalities. A variety of other accidents such as run over, fell from, crushed by and fire/explosion accounted for the other 50 percent of the fatalities. The frequency and percentage of farm tractor-related fatalities by accident type are illustrated in Table 3.5.

Except for fatalities, McKnight (1984) provided no information on other tractor-related injuries as well as the distribution of injury severity associated with tractor-related injuries. In this study, data on the severity distribution of tractor-related injuries published by Hoskin et al. (1988b) was adopted for the risk analysis of tractor-related injuries. Table 3.6 illustrates the distribution of tractor-related injuries by severity and type of accident. Sideways overturns accounted for 50 percent of fatal injuries, while PTOs were associated with early 29 percent of permanent injuries. PTO-related injuries often involve entanglement which usually causes different injuries from other tractor-related accidents. In addition, there is no agreement among agricultural engi-

Table 3.5. Frequency of Farm Tractor-related Fatalities, 1975-1981

Accident Type	Frequency*	Percentage
Overturn	1,159	49.72
Run over	263	11.28
Fall from	300	12.87
Crushed by	258	11.07
Fire/Explosion	20	0.86
All other (including miscellaneous)	331	14.20
Total	2,331	100.00

* Fatal injuries to children under age five are excluded because those fatalities are not considered as work-related.

Source: U.S. Agricultural Equipment Fatalities, 1975-1981 (McKnight, 1984).

Table 3.6. Distribution of Tractor-related (including PTO) Work Injuries By Severity and Type of Accident*

Accident Type	Injury Severity					All Injuries
	Slight	Severe	Permanent	Fatal	Unknown	
Collision from side	1.9	1.9	0.0	0.0	0.0	1.8
Collision, head-on	1.9	0.0	14.3	12.5	0.0	1.3
Collision, rear	3.7	0.6	0.0	12.5	0.0	1.8
Equipment failure	3.7	5.1	0.0	0.0	0.0	4.3
Fall	27.7	31.9	0.0	0.0	50.0	28.9
Fire	1.9	1.9	0.0	0.0	0.0	1.8
Overturn, backward	0.0	1.9	0.0	12.5	0.0	1.8
Overturn, sideways	7.4	8.3	14.3	50.0	0.0	9.6
PTO	3.7	5.7	28.6	0.0	0.0	5.7
Other, unknown	48.1	42.7	42.8	12.5	50.0	43.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
All types	**23.7**	**68.8**	**3.1**	**3.5**	**0.9**	**100.0**

* All figures in the table are percentages.

Source: Agricultural Tractor-related Injuries: A 35-state Summary (Hoskin et al., 1988b).

neering professionals on whether PTOs should be considered as a part of the farm tractor or a part of the farm machine. Therefore, the PTO-related injuries were separated from tractor-related injuries in the risk analysis of tractor hazards. With the PTO-related injuries excluded, the severity distribution of tractor-related injuries was derived and is given in Table 3.7. Based upon the severity distribution, the frequency of injuries for each severity level resulting from tractor-related accidents were projected from the tractor fatality data (McKnight, 1984), for tractors with and without ROPS. The results are shown in Table 3.8.

Furthermore, in the case of lacking reliable data, farm safety experts were consulted for their opinions, judgements and expertise on the likelihood of an accident resulting from exposure to farm hazards and on how variables could influence the rates and severity of farm injuries. Rowe (1977) stated in the discussion of risk assessment methods that "Technical value judgement" can be elicited from experts, "in the absence of hard technical information, when faced with the difficulties in obtaining further information". Farm safety experts have a vast knowledge about the causes of farm accidents, the hazards associated with various agricultural activities and the countermeasures to prevent or reduce the accidents. Therefore, the experts are able to provide a variety of information, explain their lines of reasoning, and make an invaluable judgement on issues where data have not been collected. The experts selected for this study are Dr. Robert A. Aherin at University of Illinois, Mr. David L. Baker at University of Missouri, Dr. Glen H. Hetzel at Virginia Polytechnic Institute and State University, and Dr. Dennis J. Murphy at Pennsylvania State University. By using the selected data sources and farm safety experts, the probability of accidents associated with various risk factors as well as the severity levels of injuries were estimated.

Table 3.7. Distribution of Tractor-related (excluding PTO) Work Injuries By Severity and Type of Accident*

Accident Type	Injury Severity					All Injuries
	Slight	Severe	Permanent	Fatal	Unknown	
Collision from side	2.0	2.0	0.0	0.0	0.0	1.9
Collision, head-on	2.0	0.0	20.0	12.5	0.0	1.4
Collision, rear	3.8	0.6	0.0	12.5	0.0	1.9
Equipment failure	3.8	5.4	0.0	0.0	0.0	4.6
Fall	28.8	33.8	0.0	0.0	50.0	30.6
Fire	2.0	2.0	0.0	0.0	0.0	1.9
Overturn, backward	0.0	2.0	0.0	12.5	0.0	1.9
Overturn, sideways	7.7	8.8	20.0	50.0	0.0	10.2
Other, unknown	49.9	45.3	60.0	12.5	50.0	45.6
Total	100.0	100.0	100.0	100.0	100.0	100.0
All types	**24.2**	**68.8**	**2.3**	**3.7**	**1.0**	**100.0**

* All figures in the table are percentages.

Table 3.8. Work Injuries by Severity for Tractors with and without ROPS

Work Environment	Injury Severity**			
	Slight	Severe	Permanent	Fatal
Severity distribution* (%)	24.2	68.8	2.3	3.7
Tractor with ROPS	15,246	43,344	1,449	2,331
Tractor without ROPS	8,045	22,871	765	1,230

* One percent unknown severity of injuries was not included.

** Injuries exclude those occurring to children under age five.

Assumptions

By using available data and by consulting with the farm-safety experts, the following assumptions were made for the purpose of the risk analysis of farm injuries associated with various risk factors:

1. Family members and hired workers are exposed to the same farm hazards and thus have the same injury severity distributions.

2. The overall severity of injuries for male workers is 1.5 times more severe compared to the overall severity of injuries for female family members or hired female workers.

3. Serious tractor-related injuries and fatalities resulting from overturns can be significantly reduced if tractors are equipped with ROPS and seat belts are properly used. Schnieder (1990) reported that all operators who stayed inside the safety zone of the ROPS had survived from tractor overturns in Nebraska during the period of 1969 through 1990. However, he also disclosed that a few operators were thrown from tractors and died from the injuries. Seat belts were probably not used among these fatalities. The data available from Sweden also indicated that ROPS can prevent almost all tractor rollover deaths (Springfeldt and Thorsen, 1987). Therefore, it was assumed in the risk analysis that 95 percent of the fatalities resulting from tractor overturns could have been prevented if a ROPS had been present and a seat belt had been properly used.

4. Severity distribution of tractor-related injuries is not available in the literature for tractors equipped with ROPS and cabs and without ROPS. In addition, proper use

of seat belts along with ROPS will also effect the injury consequences of tractor-related accidents. Existing data does not specify the severity distribution of injuries for the following situations:

- tractors without ROPS
- tractors equipped with ROPS but no seat belts used
- tractors equipped with ROPS and seat belts properly used
- tractors equipped with ROPS cab but no seat belt used
- tractors equipped with ROPS cab and seat belt properly used

The severity distribution of injuries resulting from tractor-related accidents under each of the above conditions could be different. However, due to a lack of quantitative information during this study, it was assumed that the severity distribution of injuries (or ratio of injury severity) resulting from tractors without ROPS is the same as those received if ROPS were present.

Example of EIC Index Calculation

As one example to illustrate how the EIC indices were computed, the following is the calculation procedure to obtain EIC indices for farm-family members grouped by age of workers.

Using the injury data classified by severity for farm-family members as given in Table 3.2, the total expected injury costs can be calculated for each age group by adding up the product of the injury frequencies and estimated cost of each level of injury severity using Equation (3.1). The total expected injury cost per million hours of work exposure, CR, was then derived from Equation (3.2) for each age group. Using Equation (3.3), the weighted average of the expected injury cost rates for family-farm workers was obtained. Finally, the EIC index for each age group of family members was computed from Equation (3.4). Table 3.9 depicts the results of the total expected injury cost, hours of work exposure, the total expected injury cost per million hours of farm work (CR), weight factor and EIC index for the farm-family members grouped by age of workers. The weighted average of the total expected injury cost rate for family farm workers was computed as $1.05 per hour of farm work.

Table 3.9. Calculation of EIC Index for Family Members

Age Group	Expected Injury Cost (million dollars)	Work Exposure (million hours)	CR[1] ($/hr.)	Weight Factor[2]	EIC Index[3]
5 - 14	9.15	8.13	1.126	0.050	1.072
15 - 24	25.36	23.91	1.061	0.147	1.010
25 - 44	50.74	56.63	0.896	0.349	0.853
45 - 64	66.81	64.02	1.044	0.394	0.993
65 or above	18.63	9.78	1.905	0.060	1.813
Weighted average			1.051		

[1] CR denotes the total expected injury cost per million hours of work exposure.

[2] Weight factor is based on the number of work hours per age group.

[3] EIC index equals CR divided by the weighted average.

Chapter 4

Results and Discussion

Discussion of Results

Based upon the risk assessment analysis of the farm injury data, the Expected Injury Cost (EIC) indices for the risk factors considered were computed. All calculated EIC indices for farm workers and activities are presented in Table 4.1. A discussion of these EIC indices will clarify the importance of each risk factor.

Employment status: The 35-state accident-survey data shows a significantly higher injury rate for hired farm workers than for family members. In calculating the EIC indices for the two groups, it was assumed that family members and hired workers had the same work exposure and the same injury severity distribution. Therefore, a hired employee would expect to have a greater EIC index than a family farm worker. The EIC index was computed as 1.085 for the hired employees and 0.975 for family farm workers. The

Table 4.1. Expected Injury Cost (EIC) Index for Farm Workers and Activities

Risk Factor	EIC Index
Employment status:	
Family member	0.975
Hired worker	1.085
Gender of farm worker:	
Family member	
Male	1.180
Female	0.475
Hired worker	
Male	1.050
Female	0.549
Age of farm worker:	
Family member	
5 - 14	1.072
15 - 24	1.010
25 - 44	0.853
45 - 64	0.993
65 or above	1.813
Hired worker	
15 - 24	1.026
25 - 44	1.102
45 - 64	0.616
65 or above	1.679
Type of farming operation:	
Beef	0.635
Dairy	1.356
Grain	1.184
Fruit	0.014
Other	0.941
Work environmental conditions:	
Tractor equipped with ROPS	0.691
Tractor without ROPS	1.309

higher EIC index for the hired labor indicates that proper training programs may be necessary for these workers.

Gender of farm worker: As illustrated in Table 4.1, the calculated EIC index for male-family members are approximately 2.5 times the EIC index of female-family members. Male hired workers have 1.9 times the EIC index of female hired workers. Both injury frequency and severity were found to be related to gender of farm workers by several researchers (Hoskin et al., 1988; Aherin, 1991; Murphy, 1991). Male farm workers generally experienced more injuries than females. Injuries to males were much more severe than those to female-farm workers because males generally have relatively greater exposure to tractors, machinery and animals which often cause more severe injuries. Reports by Karlson and Noren (1979) and Jepsen (1981) supported this conclusion. Based on studies of tractor fatalities in Wisconsin and Kansas, Karlson and Noren (1979) and Jepsen (1981) found that tractor-related deaths occurred almost exclusively among male farm workers; females accounted for less than two percent of the tractor-related fatalities in these two states. Therefore, higher EIC indices are expected for male farm workers. Another reason for females having a lower expected injury cost than male workers is probably due to additional cautions taken by female workers when they perform farming activities.

Age of farm worker: Experience, safety consciousness, and health status significantly differ from one age group to another; thus the injury frequency and severity for different age groups also vary. In calculating EIC indices for the different age groups, this study excluded the age group from five to 14 years for the hired employees because children under age 15 years cannot be legally hired for almost all types of farm work.

The computed EIC indices indicate that farm workers 65 and older were more prone to costly injuries than any other age groups, for both family members and hired workers. Generally, as the farm workers mature, they gain more knowledge and experience with farming activities which should lower the likelihood of work-related injuries. However, for farm workers in the age group 65 or above, their physical strength and health status probably have more impact on the occurrence and severity of farm work-related injuries. Comparing the EIC indices for family-farm workers, an EIC index of 1.813 was observed for people age 65 or older versus 0.993 for the age group of 45 to 64 years. The EIC index for the hired farm workers aged 65 or above is 1.679, compared to an EIC index of 0.616 for the age group 45 to 64.

The EIC index for hired employees aged 45 to 64 appears questionably low, compared to the EIC index for family members in the same age group. The low EIC index is probably related to underreporting or sampling error. Fewer than expected number of permanent injuries and fatalities among farm employees of age 45 to 64 were reported from the 35-state farm accident surveys.

Farm children age five to 14 have an EIC index of 1.072 which is higher than the EIC indices for all other farm-family age groups but 65 or above. However, the figure still appears lower than expected, compared to findings from other studies regarding injuries and fatalities occurring to farm children. Rivara (1985) estimated that about 300 children die and another 23,500 are injured on U.S. farms every year. Studies by Pfister and Hofmeister (1969), Hoff (1970) and Jester (1985) indicated that farm children under the age of 15 years were more likely to be injured as a result of farm accidents. However, recognizing that the farm is not only a workplace for farm families, but also a playground for farm children, the reported injuries and fatalities among farm children were probably not all work-related. Therefore, further investigation is needed concerning work-related and non-work related injuries and fatalities occurring to farm children so that the necessary countermeasures can be developed.

Hours of exposure to farm work: The average working hours per farm worker, including family members and hired employees, full- and part-time farm workers, were calculated to be 1,100 hours per year from the 35-state farm accident survey data (Hoskin et al., 1988a). However, the farm safety experts consider this figure is too low because farmers normally tend to underestimate the number of hours spent doing routine chores. The experts' estimate of the average number of work hours per worker is about 1,500 hours per year. The EIC index can be derived by dividing the actual working hours of a farm worker by the average of 1,500 hours. If a farmer works more than 1,500 hours in a year, then he would be expected to have more accidents and a greater EIC index. In contrast, if the farm worker works less than 1,500 hours in a year, there would be less chance for him to be injured as a result of work-related accidents. Therefore, a smaller injury cost would be expected.

Type of agricultural operation: Different types of farming operations present a range of exposures to hazards; therefore, the probability of accidents occurring and the severity of injuries vary from one farming enterprise to the next. The computed EIC indices indicated that a dairy farmer, with an EIC index of 1.356, would have the greatest expected injury cost, while a fruit farm worker, with an EIC index of 0.014, would be expected to have the least injury cost resulting from farm accidents. It is common for a farm to have several agricultural operations. In this case, a weighted EIC index would be computed based upon the percentage of time devoted to each farming operation.

On-farm environmental hazards: As an example, one hazardous condition concentrated on in this study was tractors without ROPS. Comparing the calculated EIC indices, one can see that tractors without ROPS have a much higher expected injury cost than tractors equipped with ROPS. The EIC index for tractors without ROPS nearly equals twice the EIC index of those equipped with ROPS. Although only one on-farm environmental hazard was analyzed in this study, other hazardous conditions such as PTOs without protective shields and misuses of agricultural chemicals on farms can also be analyzed in a similar way if the needed information becomes available.

In assessing the risks related to hazards of tractors, the hours of exposure to tractors (or hours of tractor use) need to be considered. In other words, the EIC indices for tractors should be adjusted according to the annual tractor use. A clear picture of average number of hours the tractors are used is not available. However, a recent Virginia farm accident survey (Zhao and Hetzel, 1991) revealed that tractors without ROPS are used for about 300 hours per year and tractors with ROPS and cabs are used for about 400 hours per year. These average hours of tractor use were calculated based on the data of 1,350 agricultural tractors collected from 600 Virginia farms. Assuming these figures are correct on the national level, then the EIC index for tractors without ROPS could be adjusted by dividing the actual hours of tractor use per year by the average of 300 hours. Similarly, the EIC index for those tractors equipped with ROPS could be adjusted by dividing the actual hours of tractor use per year by the average of 400 hours. Tractors no longer in use will not be considered in the EIC index analysis.

It should be noted that the surveys resulting in the 35-state summary were conducted in the 1970s and early 1980s. The tractor fatality data from the U.S. Consumer Product Safety Commission were collected from 1975 through 1981. Due to continuous declines of farm population, changes in farm operations, and other changes that have occurred in the agricultural industry, the data may not exactly represent the work injury and fatality scenarios of today. Therefore, the most recent information should be used when it becomes available. The methodology presented in this study should be valuable regardless of the specific data base used.

Using the Risk Model for Setting Farm Safety Research Priorities

The risk analysis model proposed in this study provides a basis for defining and evaluating farm safety research priorities. The risk associated with various farm work activities can be ranked by the EIC index. An EIC index greater than one indicates that a higher probability of an accident with a greater amount of loss could result from the particular risk factor, and thus more attention should be be given to correct the hazardous environment. When the EIC index is less than one, as may be the case for a female-farm worker exposed to a relatively low environmental hazard, the expected injury costs are lower. The EIC index ranking of farm hazards or work practices may provide justification for developing countermeasures needed to prevent or reduce farm-related accidents and injuries.

Existing farm accident statistics report only the frequencies and rates of injuries, not the total expected injury costs. In addition, for the reported farm injury rates, the denominator used to compute the injury rates usually varied from one report to another depending upon researchers. Available analysis of farm injuries by the frequency and rate of injuries is not adequate for defining needed educational program and research priorities. This study indicates that, in setting and evaluating safety education and research programs, the total expected injury cost is more important than just the frequency and rate of injuries. For example, by type of agricultural operation, Table 3.3 illustrates that fruit farmers had the highest work-injury rate -- 23.5 per million hours of work exposure. However, the severity of injuries on fruit farms was much less than on other types of farms. Ninety-four injuries on fruit farms were severe, and no permanent or fatal injuries were reported. Therefore, a fruit-farm worker has the smallest EIC index as shown in Table 4.1. The EIC index indicates that the fruit farmer would expect to have the smallest loss as a result of work-related injuries, compared with other types of farm workers. This example demonstrates that the severity of injuries has more impact on the consequences of farm work-related accidents than the frequency and rate of injuries. To have the greatest impact on farm-work injury cost reduction, our limited research resources should be directed to abating the more severe farm injuries.

Based upon the assumptions and risk model used in this study, research priorities were identified. A discussion of the research priorities identified using the risk model follow.

The EIC index for tractors without ROPS indicates that increased research efforts are needed to correct the hazard resulting from using tractors without ROPS. Schnieder (1990) estimated that approximately 3.0 million farm tractors in U.S. had no rollover protective structures. This figure is probably lower than the actual number. According to the Implement & Tractor (1991) data, there are 4,622,155 agricultural tractors in use on U.S. farms in 1991. Among them, only about 30 percent are equipped with ROPS. In addition, there is considerable variation across the country and within states in the percentage of tractors equipped with ROPS. Hence, the estimated number of tractors without ROPS currently in use may reach 3.5 million in the United States.

Every year, some 300 to 400 people die and many more are severely injured from tractor overturns. To reduce the number of severe injuries and fatalities from tractor overturns, the following research should be given priority and is ranked by the author's judgement:

1. Research efforts on retrofitting ROPS on some old model tractors manufactured before 1986 to determine the reliability and feasibility of the ROPS retrofit, both technically and economically.
2. Electric sensors that warn the tractor operator of potential overturn situations so that actions can be taken to prevent tractor overturns.
3. Design of adjustable ROPS for farm tractors that are required for certain types of farming operations.
4. Economic or other incentives that will encourage farmers to retrofit ROPS on their old tractors.
5. Studies of the needs and public opinions toward federal regulations to require tractor dealers to retrofit ROPS on all used tractors before these tractors can be resold.
6. Automatic seat belt systems similar (in concept, not design) to those now installed on some passenger vehicles.
7. Techniques for changing farmers' attitudes and behaviors toward safer operation of agricultural tractors and effective use of protective devices such as tractor seat belts.

The strikingly high EIC indices for farm workers of age 65 or above suggests that increased efforts are needed to reduce the injury cost among this age group. People aged 65 or older are most vulnerable to farm tractors and machinery. A study by McKnight (1984) revealed that the fatality rate from tractor overturns for persons older than 65 equaled twice the average tractor overturn fatality rate for all other ages. From the analysis of Indiana farm fatality data, Purschwitz and Field (1986) found that about 75 percent of the fatal accidents among people 60 years of age and over involved farm tractors and machinery. The National Safety Council farm accident survey data (Hanford et al., 1982) indicated that field work and routine chores accounted for approximately 46 percent of the injuries occurring to people age 65 or older. Falls contributed to 29 percent of the injuries among this age group. Diminished coordination, poorer vision and longer response time probably all contribute to the high injury and fatality rates among older farm workers. In addition, the older farmers, who may never really retire from framing, are also more likely to use older tractors not equipped with ROPS and a shielded PTO shaft and machinery without protective guards. Based on the information given above, priorities for research to reduce the frequency and severity of injuries occurring to people age 65 or older are in rank order of importance:

1. Methods of retrofitting ROPS on some older tractors.
2. Automatic reversing mechanisms for combines and balers to reduce serious injuries from caught-in and entanglement.
3. Electric sensor controlled emergency stop devices for agricultural machinery and equipment.
4. New design of preventive guards and shields that can be easily removed or opened for maintenance and remounted or closed afterward.
5. Educational programs to promote wearing personal protective equipment.
6. Slip-resistant materials and devices specially designed for older farm workers to prevent and reduce the injuries resulting from falls.

7. Efforts to educate farm families to increase their awareness that the strength, sight and hearing of older people may have decreased, and thus will limit their ability to perform certain agricultural tasks.

Examination of the EIC indices for family members discloses that farm children age of five to 14 years have an EIC index about six percent higher than the age group 15 to 24, approximately 26 percent higher than the age group of 25 to 44, and eight percent higher than people aged 45 to 64 years. The high expected injury cost among farm children probably related to lack of experience. Special attention is required to reduce the high EIC index for farm children. The ranked priorities for research in this area include:

1. Develop effective safety educational programs specifically designed for farm children, such as computer-based safety games, to increase their awareness of hazards around the farms.
2. Efficient and effective training materials and methods to train farm youth regarding proper ways to operate agricultural tractors and machinery and perform other farming activities. The work habits and attitudes developed in people of young age will have a great impact in injury deduction and prevention.
3. Define the extent and causes of farm injuries occurring to farm children for developing needed countermeasures.

The hired farm workers appear to have higher expected injury cost than the family members (EIC index of 1.085 versus 0.975). Based on California farm-worker injury and illness statistical data, Stutter (1991) found that of all California farmworker injuries reported in 1989, 47 percent occurred to people who had been with their present employer for less than one year, and 17 percent of the injuries and illness occurred in less than one month of employment. The findings spotlight the importance of safety training for employees, particularly for new hired workers. Research is needed to develop effective and efficient training systems and methods to train hired farm employees.

By type of agricultural operation, dairy farm workers have the highest EIC index of 1.356. The EIC index for grain farmers is 1.184 and secondary to dairy farmers. Based upon the information from the 35-state surveys, routine chores and field work were involved in 57 percent of the injuries occurring on dairy farms and 41 percent of the injuries on grain farms. However, what contributes to dairy and grain farm workers having the high expected injury costs is unknown from the existing farm injury data. Therefore, further investigation of the causes of injuries occurring on dairy and grain farms is needed so that countermeasures can be developed to reduce the expected injury costs of dairy and grain farm workers.

The research priorities discussed above can be ranked according to their importance in reducing the costs of farm-related injuries. The following is a list of ten research priorities ranked from the most important to the least. It should be pointed out that the ranking is only based on the author's personal knowledge and opinions and further evaluation will be needed.

1. To determine the reliability and feasibility of retrofitting ROPS on certain older tractors manufactured before 1986.
2. To develop sensor systems that warn the tractor operator of potential overturn situations so that actions can be taken to prevent tractor overturns.
3. To discover incentives to encourage farmers to retrofit ROPS on old tractors still in use.

4. To conduct studies regarding the needs and public opinions toward federal regulations to require tractor dealers to retrofit ROPS on all used tractors before these tractors can be resold.
5. To design automatic seat belt systems for farm tractors.
6. To develop effective safety educational programs specifically designed for farm children to increase their awareness of hazards around the farms.
7. To develop efficient and effective training materials and methods to train farm youth regarding proper ways to operate agricultural tractors and machinery and perform other farming activities.
8. To develop automatic injury prevention devices for agricultural tractors and machinery.
9. To investigate the causes of injuries on dairy and grain farms so that needed countermeasures can be developed accordingly.
10. To develop effective and efficient training systems and methods for hired farm employees.

Input to Farm Insurance Premiums

Another application of the risk model is to provide input to farm insurance ratings. Insurance premiums for a farm enterprise can be adjusted according to the EIC index of each worker and the number of workers employed on the farm. The EIC index for a particular worker would be derived by combining the indices of the variables or hazards presented in Table 4.1. Then, the EIC index for each farm worker would be added up to obtain a composite risk factor for the farm enterprise. This composite risk factor provides a scientific basis for adjusting farm insurance premiums.

A risk-based rating system for farm insurance premiums could be used as an economic incentive to promote agricultural safety. Using this method, farmers or farm workers would be assessed for their injury potential and then given a choice of safety procedures to adopt. Unsafe procedures could result in higher insurance premiums. One example of a recommended safety measure would be ROPS for tractors. The insurance industry would function as a surrogate regulator to enforce certain safety interventions such as ROPS for tractors and protective shields on agricultural machinery.

Furthermore, should an insurance company establish a risk-based system for adjusting farm insurance premiums, the company might send safety inspectors to insured farms to observe work practices and inspect tractors, farm equipment, buildings, and other work environments. The inspectors would identify potential hazards around the farm and make recommendations for corrections so that losses resulting from work-related accidents could be reduced or eliminated. Standards for the safety inspections would be needed. However, with more research on farm safety, inspection standards could be established. Some farm inspection standards and manuals have already been developed or are being developed. For example, a manual of farm inspection and loss control was developed and published in 1990 by the National Association of Mutual Insurance Companies. The focus of this manual is on inspecting and evaluating farm hazards related to fire and fire prevention. In addition to safety inspections, insurance companies could also conduct safety education for farmers and farm workers on proper work safety procedures to follow.

Other Potential Applications of the Risk Model

In addition to defining and evaluating safety education and research priorities and providing input to farm insurance ratings, the risk model proposed in this study could also have potential applications in the safety management and injury control of a farm enterprise, and provide a guideline for the systematical collection of farm injury data.

Farm Safety Management

The risk based approach could also be useful in the safety management and loss control for a farm enterprise. Actions and safety measures can be taken based upon the EIC index. For example, the high EIC index for farm workers aged 65 years or above indicates that certain farming activities, such as operating farm tractors, may no longer be suitable for people in this age group and reassignment of workers would probably reduce the likelihood of accidents. Moreover, a high EIC index could convey risk information to farmers or farm workers to increase their awareness of specific farm hazards. The farm worker might respond by taking additional precautions when performing these activities, or by using personal protective equipment to prevent accidents.

Guideline for Systematically Collecting Farm Injury Data

The development of injury surveillance or information systems is a very high priority for advancement of agricultural safety research. The risk model is specially useful since it can give direction to systematic collection of the necessary data on specific types of injuries related to specific farm hazards. The data will provide better understanding of the causes of farm accidents so that more effective countermeasures and interventions can be developed.

In addition to farm tractors without ROPS, other serious hazards on farms should be considered in the risk model. Those significant hazards include:

- PTOs without protective shields,
- misuse of agricultural chemicals,
- hazards associated with animals,
- missing protective guards on certain moving parts of farm machinery and equipment,
- hazards related to use of electrical equipment.

Hazards involving agricultural machinery require special attention because farm machinery and equipment contribute greatly to the majority of severe and fatal injuries occurring on U.S. farms. Some agricultural machinery and equipment that should be included in the risk model are PTO shafts, cornpickers, combines, balers, fork lifts, front end loaders, farm wagons and trailers, grain augers and elevators, silo loaders and unloaders, manure spreaders, farm mowers, disks and other harrows, post hole diggers, and chain saws.

Sensitivity Analysis

Due to unavailable and incomplete data, assumptions were made during the risk analysis of farm-related injuries. To determine the impact of these assumptions on the research priorities established, a sensitivity analysis was conducted. The analysis was performed by changing the following variables:

- The overall injury severity ratio of male workers versus female farm workers;
- The percentage of the fatalities resulting from tractor overturns which would be prevented if the tractors were equipped with ROPS and seat belts were properly used;
- The estimated cost of a permanent injury;
- The estimated cost of a fatal injury.

The results of these analyses are presented in Table 4.2 to 4.5. The sensitivity analysis was not performed on the assumption that family members and hired worker are exposed to the same farm hazards and have the same injury severity distribution, because the farm-safety experts had the same opinions on this issue. The costs of slight and severe injuries were not included in the sensitivity analysis since their influence on the EIC indices are not considered to be significant.

The results in Table 4.2 show that the EIC indices for male and female farm workers change with the injury severity ratio. However, the conclusions drawn from the EIC index ranking will be the same. That is, male workers would expect to have higher injury costs from farm accidents than female workers.

The hazard exposed by using tractors without ROPS versus those equipped with ROPS does not vary with changing the percentage of fatal accidents from tractor overturns that could have been prevented if tractors were equipped with ROPS and seat belts were properly used. As illustrated in Table 4.3, under all three conditions , tractors without ROPS have a significantly higher EIC index than tractors with ROPS.

Table 4.2. **Expected Injury Cost (EIC) Index for Male and Female Worker**

Risk Factor	**EIC Index**		
Injury severity ratio (M/F):	1.25	1.50	1.75
Gender of farm worker:			
Family member			
Male	1.150	1.180	1.198
Female	0.555	0.475	0.413
Hired worker			
Male	1.039	1.050	1.058
Female	0.651	0.549	0.474

Table 4.3. Expected Injury Cost (EIC) Index for Farm Tractors

Risk Factor	EIC Index		
% of overturn fatalities prevented:	85	90	95
Work environmental conditions:			
Tractor equipped with ROPS	0.732	0.712	0.691
Tractor without ROPS	1.268	1.288	1.309

Table 4.4. **Comparison of Expected Injury Cost (EIC) Index for Different Permanent Injury Costs**

Risk Factor	EIC Index		
Cost for a permanent injury:	$1,500,000	$2,000,000	$2,500,000
Age of farm worker:			
Family member			
5 - 14	1.127	1.072	1.035
15 - 24	0.995	1.010	1.020
25 - 44	0.840	0.853	0.861
45 - 64	0.997	0.993	0.991
65 or above	1.853	1.813	1.788
Hired worker			
15 - 24	1.043	1.026	1.013
25 - 44	1.136	1.102	1.075
45 - 64	0.550	0.616	0.664
65 or above	1.497	1.679	1.819
Type of farming operation:			
Beef	0.666	0.635	0.615
Dairy	1.320	1.356	1.380
Grain	1.182	1.184	1.183
Fruit	0.017	0.014	0.011
Other	0.949	0.941	0.936
Work environmental conditions:			
Tractor equipped with ROPS	0.691	0.691	0.691
Tractor without ROPS	1.309	1.309	1.309

Table 4.5. Comparison of Expected Injury Cost (EIC) Index for Different Fatal Injury Costs

Risk Factor	EIC Index		
Cost for a fatal injury:	$1,250,000	$1,500,000	$1,750,000
Age of farm worker:			
Family member			
5 - 14	1.042	1.072	1.100
15 - 24	1.018	1.010	1.002
25 - 44	0.860	0.853	0.846
45 - 64	0.991	0.993	0.995
65 or above	1.791	1.813	1.836
Hired worker			
15 - 24	1.019	1.026	1.035
25 - 44	1.078	1.102	1.120
45 - 64	0.658	0.616	0.580
65 or above	1.797	1.679	1.586
Type of farming operation:			
Beef	0.620	0.635	0.649
Dairy	1.375	1.356	1.338
Grain	1.182	1.184	1.182
Fruit	0.014	0.014	0.013
Other	0.938	0.941	0.946
Work environmental conditions:			
Tractor equipped with ROPS	0.691	0.691	0.691
Tractor without ROPS	1.309	1.309	1.309

As shown in Table 4.4 and 4.5, the uncertainty regarding magnitude of costs for permanent and fatal injuries used in the risk analysis have little effects on the relative rankings of EIC indices within each risk factor even though the absolute values of EIC indices vary with the injury costs used. The EIC indices for tractors with and without ROPS did not change with the injury costs because the severity distributions of injuries resulting from tractors with and without ROPS were assumed to be the same. Since it is difficult to perform a sensitivity analysis on the severity distributions of injuries from tractors with and without ROPS, further investigation is recommended on the types of injuries resulting from tractor-related accidents.

Based upon the results of this sensitivity analysis, it can be concluded that the uncertainties on the costs associated with farm-related injuries and other variables used in the risk analysis have little impact on the priority areas for farm safety research identified by the risk model.

Chapter 5

Summary and Conclusions

Summary

A risk analysis procedure was proposed for farm work-related injuries. The risk was defined as the Expected Injury Cost (EIC) index, per farm worker, per year. Four steps were involved in the risk assessment analysis of farm injuries: (1) determination of risk factors, (2) injury severity classification, (3) costs estimation, and (4) risk characterization.

Variables associated with farm work-related injuries were examined to determine their impacts on the incidence of injuries. Farm injuries were correlated with the risk factors of employment status, gender of farm worker, age of farm worker, hours of exposure to farm work, type of farming operation, and various hazardous conditions on a farm. Special attention was given to the hazards of tractors without ROPS.

Methods to classify the injury severity levels were reviewed. The National Safety Council classification of injury severity was selected for this study. The costs associated with farm-related accidents were analyzed. Major costs resulting from farm accidents include: medical expenses, losses of income and productivity, loss of timeliness, replacement labor, rehabilitation expenses, home and farm modification in cases of a permanent disability injury, costs of living supplements if a fatal injury occurred, and fees for legal actions which may follow. Damage to properties was not included since the economic consequences were not considered significant. Due to a lack of reliable cost data for farm-related injuries, this study based the expected costs for different levels of injury severity on assumptions: $50 for a slight injury, $1,000 for each severe injury, two-million dollars for a permanent injury, and 1.5 million dollars for each fatality.

The likelihood of an injury resulting from a particular risk factor was identified and then combined with the estimated costs of an injury to produce the EIC index for a particular farm worker. The EIC index for each worker would be summed for all employees on a farm to obtain a composite risk factor for the farm enterprise. The 35-state farm accident survey data was used as the main source for the risk analysis of farm injuries. In the absence of reliable data, farm safety experts were consulted for their opinions, judgement and expertise on the likelihood and severity of an accident occurring due to the exposure to farm work. They also gave opinions on how the risk factors affect the rates and severity of farm work-related injuries.

Farm safety research priorities were identified using the risk model developed in this study. A sensitivity analysis was conducted to determine the impact of the assumptions on the research priorities established. The research priorities were not influenced by the uncertainty regarding the costs of injuries and other variables used in the model.

In addition to setting farm safety research priorities, the risk-based approach may also provide a scientific basis for adjusting farm insurance premiums. Adjustment of insurance premiums or other benefits could be used as an economic incentive to promote the safety interests and awareness of farmers, farm workers, and their families, so that preventable farm-related injuries could be reduced. Other potential applications of the risk model include safety management and loss control for a farm enterprise, and serving as a guide for the systematic collection of farm injury data.

Conclusions

Based upon the results of this study, the following conclusions can be derived:

1. The risk associated with farm work, such as use of tractors, machinery and agricultural chemicals can be quantified using the Expected Injury Cost (EIC) index.
2. The severity of injuries have more impact on the consequence of farm work-related injuries than the frequency and rate of injuries.
3. Farm research priorities can be determined using the EIC index.
4. The EIC index suggested that hazards exposed by using tractors without ROPS could result in high expected injury costs. A high priority should be given to research to correct the hazards associated with tractors without ROPS.
5. Farm workers of age 65 or older have the highest expected injury cost, compared to other age groups. Increased efforts are needed to reduce and prevent the severe injuries and fatalities occurring to older farm workers.

6. The uncertainty on magnitude of injury costs for different severity levels used in the risk model has little impact on the research priorities established.
7. The risk-based approach can provide a scientific basis for adjusting farm insurance premiums. Adjustment of farm insurance premiums could be used as an economic incentive to promote farm safety.
8. The risk-based approach provides a framework for the systematic collection of farm injury data.

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