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Occupational Accidents in Finnish Agriculture - Causality and Managerial Aspects for Prevention

Doctoral Dissertation

Juha Suutarinen

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Abstract

Knowledge about the causation of accidents in agriculture is insufficient to further reduce the risk for accidents. Since in the literature review tractors were identified as a major source of accident risks in agriculture in the developed countries, case studies were focused to them in order to gain sufficient information on accident causation. The focus of the thesis was defining the problem areas of safety and means of intervention. Specifically, the applicability of the organisational accident theory for predicting and preventing accidents in family farming was studied. Furthermore, a research method was developed. It combines statistical and case studies guided by theory.

According to the results, Finnish agriculture is not notably safer than agriculture in other developed countries. Compared to working life in general, the incidence of non-fatal accidents seems to be higher for agriculture in Finland. Injuries in agriculture are more severe than in all industries on an average, resulting in more than twice the number of days of incapacity for work. The accident rate for compensated accidents of agriculture has been slightly, but statistically highly significantly, decreasing during the period 1991–2001, from 84 to 68 per 1 000 farmers per year.

The results indicate that the majority, about two thirds, of the tractor accidents occur when exiting or entering the cab or when hitching or unhitching implements. The accident risk is high during these tasks because of short task time. Therefore, these tasks are important targets for safety promotion.

As a result of this research, factors that predict higher accident risk on a farm were found. Farmers who report musculoskeletal disorders and who own many pieces of machinery appear to have a higher accident rate than farmers generally (adjusted RR=1.75, CI 1.14–2.69 and adjusted RR=2.34, CI 1.27–4.31). According to crude analysis, delays in work and exhaustion were both statistically significantly more common among farmers reporting more accidents. These risks implicate deficiencies of safety management in agriculture.

The organisational accident theory was applied for the first time to the research of accidents in agriculture or to microcompanies in general in this thesis. Application of formal general management practises or safety management practises on farms is suggested as an effective accident intervention strategy for agriculture. Achieving high-quality usability and a low threshold for implementation should be among the most important aims in machine and management tool design.

Key words: Occupational accidents, occupational safety, labour protection, agricultural engineering, management, ergonomics, work environment

Työtapaturmat Suomen maataloudessa – tapaturmien syyt, ja johtamiseen liittyvät tapaturmien torjuntakeinot

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Tiivistelmä

Maataloustapaturmien aiheuttajista tulisi tietää enemmän, jotta tapaturmariskejä voitaisiin tehokkaasti vähentää. Kirjallisuustutkimuksen mukaan traktorit ovat yksi maatalouden tapaturmariskien päälähteistä, mistä syystä tapaturmien syytekijöiden selvittämiseksi tehdyt tapaustutkimukset kohdistettiin traktoritapaturmiin. Väitöstyön tutkimuskohteena oli työturvallisuus, sen ongelma-alueet ja tapaturmien torjuntakeinot. Tutkimuksessa selvitettiin erityisesti tapaturmien aiheutumisen organisaatioteorian soveltuvuutta perheviljelmämaatalouden tapaturmien ennustamiseen ja torjumiseen. Lisäksi kehitettiin tutkimusmenetelmä, jossa yhdistettiin tilastollinen tutkimus ja tapaustutkimus teoreettisen tarkastelun ohjaamana.

Tutkimustulosten mukaan maataloustyö ei ole Suomessa työntekijöille turvallisempaa kuin muiden kehittyneiden maiden maataloustuotanto. Kun verrataan työturvallisuutta työelämään yleensä Suomessa, tapaturmia näyttää sattuvan maataloudessa suhteellisesti ottaen enemmän. Maataloustapaturmat ovat keskimäärin vakavampia kuin tapaturmat muilla toimialoilla, sillä ne johtavat yli kaksinkertaiseen työkyvyttömyyden kestoon verrattuna teollisuuden keskiarvoon. Maatalouden korvaukseen johtaneiden tapaturmien määrä on laskenut lievästi, mutta tilastollisesti merkitsevästi vuodesta 1991 vuoteen 2001.

Tulosten perusteella pääosa, noin kaksi kolmasosaa traktoritapaturmista, sattuu ohjaamoon ja ohjaamosta kuljettaessa tai työkoneiden irrotukseen ja kiinnitykseen liittyen. Näiden työvaiheiden tapaturmariski on suuri, koska tehtäviin käytetty aika on suhteellisesti ottaen vähäinen. Siten nämä työvaiheet ovat tärkeitä kohteita työturvallisuustyölle.

Tutkimuksen tuloksena löydettiin tekijöitä, jotka ennustavat maatilalla suurempaa tapaturmariskiä. Niille viljelijöille, joilla on paljon koneita ja joilla esiintyy tuki- ja liikuntaelinvaivoja, näyttää sattuvan enemmän tapaturmia kuin viljelijöille keskimäärin Poisson-regressiomallin perusteella (riskisuhde=2,34, luottamusväli 1,27–4,31 ja riskisuhde=1,75, luottamusväli 1,14–2,69). Vakioimattomien riskisuhteiden perusteella töiden viivästymiset ja voimakas väsymys olivat molemmat tilastollisesti merkitsevästi yleisempiä

viljelijöillä, joille sattui enemmän tapaturmia. Nämä riskitekijät viittaavat turvallisuusjohtamisen puutteisiin maataloudessa.

Tässä tutkimuksessa sovellettiin ensimmäistä kertaa tapaturmien aiheutumisen organisaatioteoriaa maatalousyrittäjien, tai yleensä mikroyritysten, tapaturmatutkimukseen. Teorian soveltaminen toi lisäarvoa tutkimukseen perinteisiin lähtökohtiin verrattuna. Maatalouden työturvallisuuden parantamiseksi olisi kehitettävä ja otettava käyttöön maatilan turvallisuusjohtamiseen tai johtamiseen yleensä soveltuvia menetelmiä. Tällaisten menetelmien sekä koneiden korkeatasoinen käytettävyys ja matala kynnys käyttöönotolle pitäisi olla niiden suunnittelu- ja kehitystyön tärkeimpiä tavoitteita.

Avainsanat: Työtapaturmat, työturvallisuus, työsuojelu, maataloustekniikka, liikkeenjohto, ergonomia, työympäristö.

Foreword

This thesis is based on projects conducted 1988–1995 at the University of Helsinki's Department of Agricultural Engineering (at present, the Department of Agricultural Engineering and Household Technology) and 1995–2003 at MTT Agrifood Research Finland, Agricultural Engineering Research (known as Vakola). There have been many fellow scientists and others in these organisations who have supported and helped me in the projects during the course of the years. I want to express my warm thanks to all of you; without this collegial support, this work would never have been possible. I want to acknowledge the Farmers' Social Insurance Institution (Mela) and the Academy of Finland for the major funding of this work.

I express my gratitude to the mentor of my work, Professor Aarne Pehkonen, for his enduring support, guidance, and encouragement during my studies. I am also indebted to my other mentor, Professor Jorma Saari, for inspiring talks about the theory and practise of safety science. During the difficult final stages of writing, Professor Anna-Maija Sjöberg gave invaluable, experienced, and enthusiastic help, for which I am very grateful. Besides Professor Saari, there are other people at the Finnish Institute of Occupational Health to thank for professional and enjoyable co-operation and assistance: Dr. Timo Leskinen; Jouni Lehtelä; Janne Väänänen; Pekka Plaketti; Dr. Simo Salminen, and Dr. Simo Virtanen.

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Finally, Anne, your loving support has been the force helping me manage through this ordeal.

Vihti, April 2003

Juha Suutarinen

List of original articles

The thesis is a summary and discussion of the following articles, which are referred to by their Roman numerals:

I Suutarinen, J. 1992. Tractor accidents and their prevention. International Journal of Industrial Ergonomics 10: 321–329.

II Suutarinen, J. 1997. Non-fatal tractor accidents and their prevention. Journal of Agromedicine 4(3/4): 313–324.

III Leskinen, T., Suutarinen, J., Väänänen, J., Lehtelä, J., Haapala, H. & Plaketti, P. 2002. A pilot study on safety of movement practices on access paths of mobile machinery. Safety Science 40(7–8): 675–687.

IV Suutarinen, J. 2003. Management as a risk factor for farm injuries. Journal of Agricultural Safety and Health, Accepted 2003.

The author's contribution in article III: Juha Suutarinen was responsible for the research project, conducted the statistical analysis of access path accidents, (chapters 1.1, 2.1, 3.1) and wrote the rest of the paper together with T. Leskinen, J. Väänänen, J. Lehtelä, H. Haapala and P. Plaketti.

Abbreviations and definitions

Abbreviations

CATI: Computer-assisted telephone interviewing.

GFT: General Failure Type.

Mela: Acronym for Farmers' Social Insurance Institution, formerly known by the acronym FSII.

ROPS: Roll-over protective structure.

Definitions

Accident: The dynamic mechanism that begins with the activation of a hazard and flows through the system as a series of events, in a logical sequence, giving rise to death, ill-health, injury, damage or other loss (Roland & Moriarty 1983, and BS 8800 1998 merged).

Accident rate: Number of accidents per 1 000 persons in employment.

Agricultural tractor: "'Agricultural or forestry tractor' means any motor vehicle, fitted with wheels or caterpillar tracks, having at least two axles, the main function of which lies in its tractive power and which is specially designed to tow, push, carry or power certain tools, machinery or trailers intended for agricultural or forestry use. It may be equipped to carry a load and passengers." (Council Directive 74/150/EEC 1974.) Referred to in the text synonymously also as "tractor".

Compensated accident: All accidents the casualties of which have got economical compensation including no-incapacity accidents, less than three days incapacity, and severe accidents (more than 30 days incapacity).

Farm: Agricultural enterprise.

Farm management (normative): Managing the farm, in the sense of Drucker (1999, see "management"), including the decision-making in uncertainty with integrated SHEQ (Safety, Health, Environment, Quality) approaches.

Hazard: A source or situation with a potential for harm in terms of human injury or ill-health, damage to property, damage to the environment, or a combination of these (BS 8800 1998).

Ill-health (occupational ill-health): "Ill-health that is judged to have been caused by or made worse by a person's work activity or environment" (BS 8800 1998). In this study, ill-health, illness, and disease are considered synonyms.

Incidence: The number of new cases (accidents, illnesses) occurring during a given time period (Zahm 1998).

Incidence rate: Incidence divided by the total person-time (number of persons multiplied with duration of observation) experienced by the source population (Zahm 1998).

Incident: "Unplanned event which has the potential to lead to accident" (BS 8800 1998).

Injury: "Lesion: (L. laesio; laedere to hurt) any pathological or traumatic discontinuity of tissue or loss of function of a part" (Multilingual Glossary 2000).

Management: Management is the organ (specific tool, function, instrument) that makes the institution capable of producing results outside of itself (Drucker 1999).

Management system: "A composite, at any level of complexity, of personnel, resources, policies and procedures, the components of which interact in an organised way to ensure a given task is performed, or to achieve or maintain a specific outcome" (BS 8800 1998).

Mechatronics: "Mechatronics is the synergetic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and processes" (Bradley et al. 1991).

Occupational disease: Specific illnesses defined by legislation, which are due to physical, chemical or biological factors related to agricultural work (Mela 2003).

Organisation: "A company, operation, firm, enterprise, institution, or association, or part thereof, whether incorporated or not, public or private, that has its own functions and administration. For organisations with more than one operating unit, a single operating unit may be defined as an organisation" (BS 8800 1998).

Poisson regression: "A mathematical model in which the log of the incidence rate is modeled as a linear combination of a set of risk factors" (Checkoway et al. 1989).

Prevalence: "Number of cases in a population at one point in time (point prevalence) or during some specified time interval (period prevalence)" (Checkoway et al. 1989).

Principal Operator, PO: The person, generally the owner, mainly responsible for the enterprise management and operation.

Risk: Combination of the frequency, or probability, of occurrence and the consequence of a specific hazardous event (SFS-IEC 60300-3-9 2000).

Risk Management: Systematic application of management policies, procedures and practises to the tasks of analysing, evaluating, and controlling risk (SFS-IEC 60300-3-9 2000).

Safety: The quality of a system that allows the system to function under predetermined conditions with an acceptable minimum of accidental loss (Roland & Moriarty 1983).

Safety Intervention: At the workplace level: an attempt to change how things are done in order to improve safety. At the community level: laws, regulations, standards, and programmes of governments, industries, professional bodies, and others (Robson et al. 2001).

Safety Management: An overall system developed to ensure that safety activities are properly planned, effectively implemented, and followed up (Kuusisto 2000).

Usability: The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (SFS-EN ISO 9241-11 1998).

Contents

1 Introduction

The issue of the health and well-being of the population engaged in world food production is of great importance. It is obvious that in order to be able to produce nutrition for themselves and others, the population has to have a sufficient level of working capacity. The magnitude of population engaged in food production globally is enormous. Agriculture employs half of the world labour force and it is estimated that 1.3 billion workers are engaged in agricultural production worldwide. In developed countries, however, the share of the agricultural labour force in the total economically active population is under 10% of workers, but is 59% in the less developed regions (ILO 2000).

Health is a value in its own right. The universal threat to the fundamental human rights of life and security of a person posed by unhealthy working conditions has been characterised in legal and other human rights instruments (Feitshans 1998). The constitution of the World Health Organization states that:

> *"The following principles are basic to the happiness, harmonious relations and security of all peoples:*
>
> *Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.*
>
> *The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition.*
>
> *The health of all peoples is fundamental to the attainment of peace and security and is dependent upon the fullest co-operation of individuals and states" (WHO 2002).*

The preamble to the constitution of the International Labour Organization (ILO) states that: "the protection of the worker against sickness, disease and injury arising out of his employment" is considered as a precondition to "universal and lasting peace" (ILO 2002a). However, as is well known, well-being and safety are not equally realised all over the world (Hovden 1999, Dembe 2001). The agricultural sector exposes workers to risks to physical well-being, which are among the highest ones in working life (ILO 2000; Perkiö-Mäkelä 2000, Walker-Bone & Palmer 2002).

In agriculture, there is a high risk of accidents and several types of occupational diseases (Gustafsson et al. 1991; Langley et al. 1997; Forastieri 1999, ILO 2000). It is not a coincidence that accidents are a significant source of uncertainty in the lives of farmers (Sonkkila 2002, Ristiluoma & Sipiläinen

2003). Unfortunately, this is not their only burden. Farm management is about making decisions under uncertain conditions (Thysen 2000). Uncertainty in Finnish agriculture has increased considerably in relation to the accession of Finland to the European Union (EU) and resultant policies (Katila 2000, Sonkkila 2002). Consequently, the working ability of the farming population has been put at increased risk despite the mixed blessings of technological development (Kirkhorn & Schenker 2002). Many have reached the limits of their endurance both in Finland and elsewhere (Kalimo & Toppinen 1997; Raine 1999; Kalimo & Hakanen 2000; Scarth et al. 2000, Gregoire 2002).

The structural change in agriculture is evident in the rapid decrease in the number of farms and farmers and in the increase in farm size (Ala-Orvola 2001, Mela 2002a). The availability of a skilled work force, for instance stand-ins, is unsatisfactory (Ristiluoma & Sipiläinen 2003). The uncertainty of agricultural policy and poor profitability of farming has reduced the number of people willing to engage in agriculture (Laurila 2001). Harsh work and above-average health risks do not help in recruiting. The current development increases the burden of management and consequently, the potential of modern technology to fully support the task of farm management should be understood and utilised. The well-being of the farming population will probably suffer negative effects unless the utility, safety, and usability of the developing technology are attended to.

Given all this, since nations have the ambition to maintain a certain degree of food self-sufficiency, the challenge for the policy makers should be to assure an adequate work force for food production both in numbers and quality by securing development in agriculture that is socially sustainable. After all, "economic and social policies are mutually reinforcing components in order to create broad-based sustainable development" as stated in the ILO declaration on fundamental principles and rights at work (ILO 2002b).

The "Global Strategy on Occupational Health for All" (WHO 1995) stated that occupational health is a basic element of the principle of sustainable development. Altogether ten different mechanisms of the relation are listed, including the prevention of occupational accidents and the use of the best available production technology. Furthermore, the occupational health approach will facilitate undisturbed production, which increases the quality of products, productivity, and process management and thus serves to avoid an unnecessary loss of energy and materials and to prevent an undesirable impact on the environment (WHO 1995).

In this situation, the challenge for the scientific community is to provide knowledge about the state and trends of risks related to the work ability of the work force in agriculture and the means to achieve more sustainable development. This thesis aims to add to the knowledge that is necessary for understanding and supporting socially sustainable food production. The purpose is to consider accident risks in farming, by defining problem areas of worker risks and the means of intervention. In order to specify the research questions, the literature on safety in agriculture is reviewed in the following section.

2 Literature review on safety in agriculture

2.1 Safety

Safety cannot be defined without the concepts of risk or danger. The Oxford English dictionary (2002a) defines safety: "The state of being safe; exemption from hurt or injury; freedom from danger". Risk has been defined as the combination of the frequency, or probability, of occurrence and the consequences of a specific hazardous event (SFS-IEC 60300-3-9 2000). Hazard in turn is a source or a situation with a potential harm in terms of human injury or ill-health, damage to property, damage to the environment, or a combination of these (BS 8800 1998). Safety is not a directly measurable state, but it has two sides, a negative one, and a positive one. The negative one is the materialisation of risks, for instance, in the form of an accident. These incidental absences of safety are easier to quantify than its more enduring presence (Reason 1997; Powell 1998, Petersen 2000). As for machines, safety refers to a machine's ability to perform its function without causing injury or damage to health (SFS-EN 292-1 1992). Considering human psychology, Breivik (1999) has suggested that risk and safety are complementary factors within individuals. Everyone needs a basic safety level, but also in order to develop and grow, individuals need to accept chances and risks. According to Rowe (1980), even if risk increases from the zero level, it may be acceptable, on a 'normal' level up to a certain 'non-action' level. Beyond that, risk reduction is desirable until the 'action level', above which risk is excessive and action to reduce it is required.

As noted in the introduction, safety is not an equally distributed benefit in society. A threat to safety is the risk of an accident. In the following, theories and models of accident causation are presented and concluded with the characterisation of an accident.

2.2 Accident causation

Accident research started from the pragmatic need to act on the human and monetary costs of occupational accidents. As a result, scientific efforts in this area have had, understandably, an applied nature. The problem of accidents has been dealt with by researchers from various disciplines, such as medicine, sociology, psychology, engineering, management science, and education.

Depending on the scientific background of the researcher, various theories, models, and hypotheses have been utilised to motivate the choice of factors to be studied (Harvey 1984; McClay 1989; Laflamme 1990, Adams 1992). Geller et al. (1990) have argued that the medical perspective tends to examine the farm as an environment in which workers have a high exposure to many specific diseases or conditions. The epidemiological perspective, on the other hand, tends to focus on the accident as the unit of analysis. Nevertheless, accident research, or more widely safety science, is becoming a discipline of its own (Harvey 1984; McClay 1989; Laflamme 1990, Adams 1992). Specifically, safety-related development of university research and teaching groups in Europe was a phenomenon of the 1960s and 1970s (Hale & de Kroes 1997).

Two reciprocal and occasionally merging sub-areas of the discipline can be identified, namely accident theories and accident research (or investigation) (Harvey 1984). Accident theories supply *a priori* assumptions and hypotheses as to the causes of an accident and, on the other hand, research systems are used for an applied *post hoc* analysis of accidents. Models of accident causation are based on theories and give form and guidance to investigation methods and systems. However, boundaries between theories, conceptual models, and methods are often unclear.

Accident-proneness theory, dating back to World War I, is considered the first academic attempt to explain the distribution of accidents (Häkkinen 1978; Larsson 1999, Saari 2001). The idea is that because few people have several accidents – some have one and most none – those with several accidents must have a characteristic that makes them more likely to have an accident (Raouf 1998; Larsson 1999, Howell et al. 2002). Today, this theory is considered both scientifically flawed and politically incorrect (Raouf 1998, Larsson 1999). Earlier in the academic field, and even today in media coverage of accidents and disasters, terminology used suggested that accidents have only one cause (e.g., Häkkinen 1978; Adams 1992; Seppälä 1992; Pekkarinen 1994; Booth & Lee 1995, Reason 1997). The so-called "domino theory" by H.W. Heinrich was behind the perhaps single most historically noteworthy and influential model of accident causation: the sequential causation model (Heinrich et al. 1980; Goossens & Hale 1997, Howell et al. 2002). According to this theory, to prevent an accident, essentially one had only to remove one factor from the causal chain.

Accident analysis has its origins in single and proximal factor theories. Models developed in time to more comprehensive analysis aimed to uncover more fundamental and distal factors in the organisation and work system (Harvey 1984, Goossens & Hale 1997). Laflamme (1990) classified the models into four groups: decisional, sequential, energetic and sequential, and organisational models. Decisional models emphasise the interactive dynamics of working situations and they are inspired by psychological theories in information processing. These models are built in a deterministic and algorithmic way. Sequential models are influenced by ergonomic research. The task rather than the individual is the target of interest. Accidents are defined as undesirable outputs of the system and the analytical focus is on the search for disturbances and their causes. Energetic and sequential models also study disturbances and undesirable energy transfers from the machine to the individual. Based to a systems approach, organisational and situational factors are included as well. Organisational models are inspired by socio-technical approaches and organisational theories. The focus is on the structural background factors that influence accident circumstances (Laflamme 1990). She presents a new synthesised model which stresses the interactive and multivariate nature of accident factors. The model includes both spatial and temporal information sought in accident research.

As is characteristic of a young science, many rival or complementary theories of accident causation compete. Häkkinen (1979) listed 30 accident theories by the end of the 1970s. Furthermore, the validity and reliability of accident investigation methods are seldom tested (Wagenaar & van der Schrier 1997). However, it is becoming increasingly obvious that both the systems theory approach and the theory of organisational accidents including the related Tripod model (and analysis method, Figure 1) developed by Reason, Wagenaar, Groeneweg, and others (e.g., Groeneweg 1992; Reason 1995, Wagenaar & van der Schrier 1997), are gaining the dominant position in the discipline of safety science, judging by reviews and adopted models in recent research (e.g., Hale & de Kroes 1997; Varonen 1997; Kivistö-Rahnasto 2000; Kuusisto 2000, Ruuhilehto & Vilppola 2000). This trend to focus on interactions in sociotechnical systems seems to be parallel to the progression in the discipline of ergonomics (Wilson 2000).

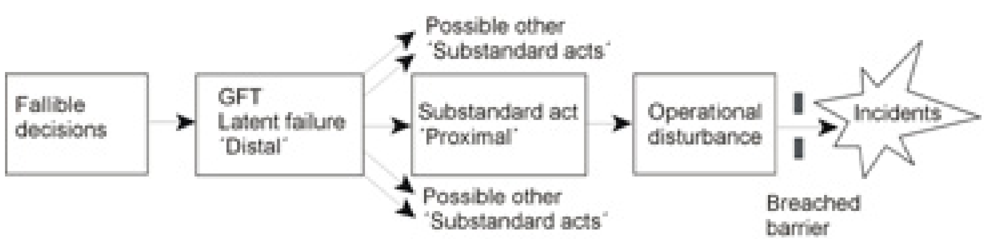

Figure 1. The Tripod accident causation model. "GFT" stands for "general failure type" (Wagenaar & van der Schrier 1997).

The Tripod model links systemic accident causes with managerial policy decisions. All parts of the model are connected. The model includes the feedback and feed forward control loops of information, for instance, from incidents to decision-making, but they are not presented in Figure 1 (see Groeneweg 1992, Reason 1997). The accident sequence begins with the negative consequences of organisational processes (e.g., decisions concerned with planning). These decisions are themselves influenced by the financial, economic and political context in which the organisation functions. However, only factors that the manager can reasonably be expected to have some control over are included. The latent failures (general failure types, GFTs, 11 pieces) so generated are transmitted to the workplace where they create conditions that promote the commission of substandard acts (i.e., errors, violations). These are termed active failures as distinct from latent failures that take place high in the organisation and are often remote from both the time and place of hazards. GFTs are said to be like diseases; they can only be seen through their symptoms, not directly. Active failures can be seen as delayed effects of system design failures. The resulting disturbances lead to incidents only if the defences are breached. Defences are barriers or other protections against hazards and their purpose is to: create understanding and awareness of hazards; give guidance on how to operate safely; provide alarms and warnings when danger is imminent; restore the system to a safe state in an off-normal situation; interpose safety barriers between the hazards and potential losses; contain and eliminate the hazards should they escape this barrier, and provide the means of escape and rescue should hazard containment fail (Reason 1995 and 1997, Wagenaar & van der Schrier 1997).

Criticism points to the fact that causal trees are not models of system functionality, but only records of particular cases and limited to the problems that underlie only one accident (Rasmussen 1997, Wagenaar & van der Schrier 1997). Wagenaar and van der Schrier (1997) argue that this weakness is somewhat reduced through the possibility of the quantitative combination of multiple-accident analysis, when the profile of accident causes is more representative for the organisation. Nevertheless, efforts to improve safety by counteracting the human error sources identified with causal analysis of accidents is seen as ineffective and consequently, the trend is toward research on occupational safety in terms of models of actual behaviour without reference to errors. Models of a higher level than tasks and acts are needed concerning the behaviour of organisations and individuals (Rasmussen 1997).

Grimaldi and Simonds (1975) propose that individuals are frequently considered the focal point of safety. However, individualised safety approaches are inadequate by themselves. According to Reason (1997), accidents can be divided into two groups: those that happen to individuals and those that happen to organisations. Organisational accidents involve many people at different levels of the enterprise. According to Rasmussen (1997), "accidents are created by the interaction of potential side effects of the performance of several decision makers during their normal work". Latent conditions relate to generic organisational processes (planning, budgeting, maintenance, procedures, communication etc.) and influence throughout the organisation to create error- and violation-producing factors (e.g., time pressure, high workload, poor interfaces) (Reason 1995 and 1997, Wagenaar & van der Schrier 1997, Figure 1). In individual accidents, a specific person may be both the agent and the victim of the accident. However, individual accidents can have organisational origins. Although it is not easy to draw a hard line between them, it is useful to treat individual and organisational accidents as distinct kinds of events (Reason 1997).

Given this, the question arises whether the accidents that a farmer in a family enterprise encounters are to be treated as organisational or individual? A farm is an enterprise with organised production processes and economic functions. In the predominant typical family-farming mode of production, the scale of the organisation, however, is small especially in regards to the size of the work force and turnover. Only a few people in the entrepreneur family with an unstable degree of participation are responsible for both business management, including strategic managerial decisions, and the day-to-day operations (see also Timonen 2000). In contrast, in large enterprises, ownership and management are intertwined. Is the theory of organisational accidents relevant for sole proprietors? The causes of organisational accidents are seen to arise from the complexity and unforeseen interaction of multiple faults of large organisations. For instance, communication failures in sole proprietor firms are not often likely to be relevant hazards. Furthermore, although complex technology may be involved in modern farming (Jongebreur 2000; Kutzbach 2000, Weick 2001), the organisation of a family farm is more transparent and intelligible to a farmer than the functions of a large multinational company are to a worker.

On the other hand, it seems reasonable to assume that if one considers the accidents of self-employed people as theoretically parallel to the accidents of employed people, differences in several important characteristics associated with entrepreneurship and accidents would be omitted. These include autonomy, motivation, stress, legislation, and supervision to name a few. For instance, if we consider violations, where do the rules of reference come from? The same person is both responsible for the latent conditions (consequences of decisions) and vulnerable to active failures (errors and violations). Glasscock et al. (1997) argue that since farmers typically work alone, the effects of individual differences will presumably be magnified since the social, organisational regulation of behaviour typical in other industrial settings is, to a large extent, absent. Nevertheless, according to systemic accident theory, the farmer does not operate in isolation. Individual accidents have their roots in common systemic processes. As human errors are seen as consequences rather than causes and behaviour is governed by the interplay between psychological and situational factors, the individual, the manager, is obviously one of the key subjects for research, but the influence of the production organisation cannot be excluded either.

The environment must be considered as well. The proximal environment, the farm, has a group of properties that a farmer can influence by management, and another set of properties or consequences of environment in the farm and in the society over which the farmer has only limited control. The environment, in turn, influences the operator, for instance, as a source of hazards. According to Rasmussen (1997), a very aggressive and competitive societal environment will focus the incentives of managers on short term financial and survival criteria rather than long-term criteria concerning welfare, safety, or environment. Consequently, at least for large-scale industrial systems, Rasmussen (1997) suggests that the adaptive behaviour of organisations under pressure is an important research issue. Three basic loosely-grouped and interrelated factors for causes of accidents can be defined hereafter for research on accidents of the self-employed: environmental and personal factors, and management decisions (see also Heinrich et al. 1980).

Glasscock et al. (1997) have formed a model for farm accidents that seems to be in agreement with the theoretical discussion above (Figure 2). It combines all of the relevant factors in causation of accidents among the self-employed. According to the model, risk situations arise as a function of both personal and environmental factors. Personal factors include, for instance, perceptions, knowledge and safety attitudes. A farm is characterised by its type and size, and safety standard of its farm machines. Assuming that farmers have a strong influence on their own work environment, Glasscock et al. (1997) have proposed two types of safety-relevant behaviour. Firstly, farmers can, via regular planning, maintenance, and safety checks (referred here hereafter as to management), improve the safety standards of the environment. Secondly, farmers can behave in a more or less safe fashion while working in a risk situation. It should be noted that in addition to behaviour A in the model, decisions about the environment involve the implementing of production processes and working methods as well (e.g., the choice of production technology) and more long-term strategic decisions which contribute to the risks. The degree of safety motivation and safety awareness related to these decisions is a matter of interest.

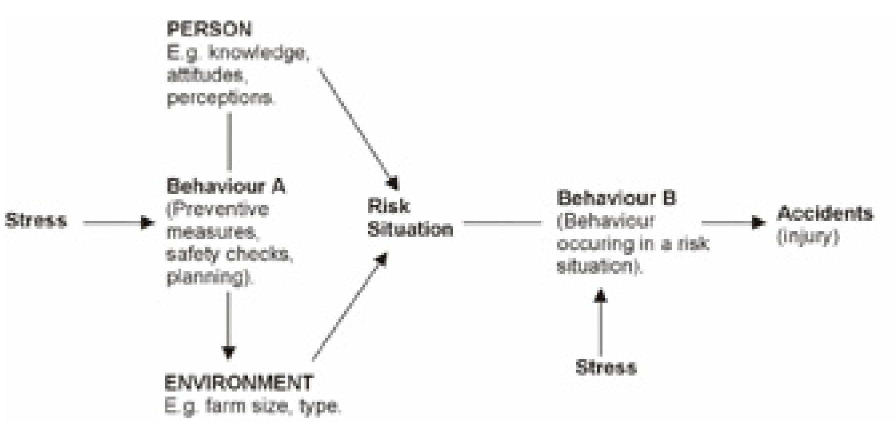

Figure 2. Model of farm accidents (Glasscock et al. 1997).

A comparatively high prevalence of burnout, depression and stress in the agricultural population has been reported (Kalimo & Toppinen 1997; Kallio 1997; Raine 1999; Kalimo & Hakanen 2000; Scarth et al. 2000, Ristiluoma & Sipiläinen 2003) and mental stress and depressive symptoms seem to relate to the increased risk of an accident (Geller et al. 1990; Erikson 1996; Thu et al. 1997; Zwerling et al. 1998; Rasmussen et al. 2000, Park et al. 2001). The psychological or physical stressors have a typically degrading influence on information processing and cognition and hence errors are more likely to occur (Wickens & Holland 2000), leading to increased accident probability. For the examination of the mechanism of mental stress both in organising operations and in their physical implementation, the model of Niemelä and Teikari (1984) is available, for instance. More recently, Kidd et al. (1996) have presented a model of farm family stress and accidents.

Stress may affect both types of behaviour. The quality and degree of management can be reduced, risk taking may be increased, and cognitive functioning (attention, concentration) may be reduced. Stress, however, is a complicated factor to analyse or study because it can have multiple roles as an effect, cause, and modifier (Dembe 2001). An arrow going from accidents back to the personal variables, describing the influence of an individual's accident history on attitudes and behaviour, could present feedback or time dimension. For instance, long-term risk taking which does not result in accidents will reinforce the tendency to take risks (Glasscock et al. 1997). However, prior agricultural injury has been reported to be associated with higher injury rates (Browning et al. 1998, McGwin et al. 2000), suggesting that environmental factors, risk taking differences, or resultant disabilities are more influential than learning in the long term. Accident repetitiveness is generally a well-established fact, but according to Groeneweg, (1992) it should not be confused with accident proneness.

It has been suggested that human errors can be divided into 13 different types depending on if the performance is skill-, rule- or knowledge-based in the inner control of human activity (Reason 1990). Nevertheless, if applying only behaviour-based theory, the number of accidents can be reduced if the number of accidents is rather large in the enterprise (intervention by measures influencing hazards of the work environment and equipment are effective in that case also). When a certain better level of safety has been achieved, further improvement of safety can be achieved only by decreasing general failures in the operations of the organisation (Groeneweg 1992). Furthermore, there is a relationship between error types and pre-existing work practises. Individual worker practises are associated with skill-based errors, whereas management practises are related to knowledge-based errors (Feyer et al. 1997). This result has implications for prevention and emphasises the need to include management issues to safety research of the self-employed.

However, accident research is but one tool of occupational safety research which is defined by Linn and Amendola (1998) as " the study of the incidence, characteristics, causes and prevention of workplace injury". In conclusion, in research on farm accidents, the individual, behavioural aspect and organisational accident theory have to be considered in combination. This is necessary since, in the case of sole-proprietorship, personal characteristics and behaviour may strongly influence management decisions, which in turn affect the safety of the enterprise.

Characterisation of an accident

Accidents are not random events, but result from cause and effect relationships. Therefore, accidents are predictable and preventable (Linn & Amendola 1998). The accident causation paradigm adopted in this thesis is systemic, in which the causes of accidents are a network of several simultaneous and sequential events and circumstances. The relation between two factors may be deterministic or probabilistic in various degrees. Both direct, proximal causes and indirect latent causes exist in the process of an accident. Accident factors are located in the environment (incl. machinery and tools, for instance), persons, and procedures (incl. management and organisation among others). The general definition of an accident given in BS 8800 (1998) is supported in this thesis, although mainly injurious accidents are dealt with.

2.3 Accidents and work in agriculture

Change in work

Changes in the nature of work result from change in society and the global economy. According to Martin (2001), world agriculture is undergoing remarkable changes. He identifies five drivers of change: environmental controls and regulations; industrialisation of agriculture; shift from commodities to differentiated products; food supply chain, and knowledge-intensive agriculture. All these developments have combined influences on the work of a farmer, but only a few of these issues are discussed here.

Agriculture is an industry that is closely connected to nature and biology. Advanced technology must be utilised in order to fully take advantage of the potentiality provided by nature, and to preserve and even enhance natural productivity (Pehkonen & Mäkinen 1998). Indeed, the change in agricultural work has been largely characterised by mechanisation. Agricultural mechanisation is defined as the use of any machine to accomplish a task or operation involved in agricultural production (Odigboh 1999). Since the three levels of agricultural mechanisation involve hand-tool technology, draft-animal technology and engine-power technology, it is clear that agriculture anywhere has always been mechanised (Odigboh 1999). In industrialised countries, the limited, ineffective, and inefficient use of man and draft animal power has been greatly replaced by engine-power technology (Barger et al. 1952, Luder 2001). Nowadays, the major activity in agriculture is the operation of the equipment subsystem (Hunt 1986). In spite of the rapid evolution of mechanisation, strenuous manual tasks are still common in certain areas of agriculture, for instance in small farms and in relation to bovine tending. These tasks result in common musculoskeletal disorders among farmers (Manninen 1996; Perkiö-Mäkelä 2000, Kirkhorn & Schenker 2002).

However, new challenges for operating the equipment subsystem have emerged. A high-tech scenario for the future of the Finnish agriculture suggested by Pehkonen and Mäkinen (1998) presents the idea of enhancing the quality grade and related expertise level throughout the entire production chain. This calls for improved knowledge-intensive management for farmers and high-quality management of information. Engineering solutions must support positive development, for instance, by good usability and safety (see also Haapala 1998; Pesonen 1998, Pesonen & Haapala 1998). Other challenges result from the increasing size of machinery. Strenuous and hazardous manual tasks still required when connecting ever heavier implements to big tractors are an example of a compatibility and usability issue which calls for study and solution.

Industrialisation and the supply chain mentality involve the application of modern management approaches to agricultural production. Knowledge-intensive management is linked to the use of information-based decision systems (Martin 2001). However, the adoption rate of information systems and management tools in general has not been as expected (Öhlmer et al. 1998; Thysen 2000, Kuhlmann & Brodersen 2001). Emerging technologies as such are a driver of change (Pollock 2000, Weick 2001). Biotechnology and information and communication technology are examples of technologies which influence work. In their study of safety and health implications related to the adoption of biotechnology and information technology in agriculture, Shutske and Jenkins (2002) conclude that the characteristics of employers, workers, inputs, production practises and the socio-economic environment are likely to change. Writers state that millions of dollars have been spent on issues related to risk assessment of food safety and environment protection, but little research has been done related to worker safety.

To remain competitive, farmers are forced to continually increase their productivity. In Finland, joining the EU resulted in the need for a farmer to increase the amount of work by 17% in order to maintain the previous income. The share of business management tasks increased as well (Hirvonen 1997). Modern agriculture calls for the evolution of versatile skills for the farmer and endurance of stress because of uncertainties due to natural, market, and institutional risks. On the other hand, knowledge-intensive management is predicted to reduce uncertainties in farming (Aakkula et al. 2002).

The major obvious trend and change in the work of a farmer in industrialised countries appears to be the shift from work characterised by physical activities to more cognitive, mentally-dominated farm management. For instance, automation, mechatronics, and intelligent machinery may relieve the operator from manual control, but instead higher-level control, decisions, and choices have to be made (see also Haapala 1998, Rikkonen 2003). In relation to this development, more long-term effort and concentration is needed in work. Physical fatigue does not divide the task naturally into periods of work and rest as much as earlier. Besides, tasks involving mainly cognitive efforts call for the ability to focus on mental processing more than during customary manual tasks. Kutzbach (2000) predicts that work time for operating the machinery will increase due to better ergonomic design. In Finland in 1997, an average of 18% of working hours in agriculture was spent in tractor work (Tauriainen et al. 2000). The percentage varies depending on the area of production. In crop production, the share was 58%, whereas in animal production it was less than 4% (Tauriainen et al. 2000).

Technological advancement and other forces in society have had, and presumably will continue to have, both beneficial and negative impacts on work in agriculture (see Kirkhorn & Schenker 2002). According to Berge (2000), in order to keep farming an attractive occupation, the social implications of work must be acceptable for the family. The amount of work on surviving farms increases (Ristiluoma & Sipiläinen 2003), but despite technological development, nature as a production environment remains the same. Facing the evolution of new or increasing risks for population in agriculture, those involved in the discipline of agricultural engineering will be challenged for a positive impact to development (see also Jongebreur 2000).

Accident incidence

Depending on the country, time of the examination and severity of examined accidents, among other things, agriculture usually ranks among the three most hazardous sectors (Murphy 1986; Merchant et al. 1989; Geller et al 1990; Reiling 1997; ILO 2000; Dupré 2001, HSC 2001).

Globally, in 1997, 170 000 agricultural workers were estimated to have faced a fatal workplace accident, which is more than half of the total of all workplace fatalities in the world (ILO 2000). In 1999, the estimated number of accidents at work in the EU with more than three days' absence from work was for agriculture, including hunting and forestry, 373 340. The number of fatal accidents at work in the same branch was 631 in 1998 (Dupré 2001). Although agriculture is one of the most hazardous sectors according to present statistical information, it has long been realised that figures given are low estimates of the danger (Stoskopf & Venn 1985; Forastieri 1999; HSE 2000; ILO 2000, Pickett et al. 2001). The true number of accidents is considerably higher.

Comparing safety and health state in agricultural work over time and between countries and branches is problematic. Absolute accident figures, if used as an index of safety or hazard potential, are misleading in comparison. Instead, accident figures should be used in relation to some measures of exposure, such as work hours or size of population (Hoyos & Zimolong 1988, Purschwitz 1992).

Even when there are accident rates available, there is a wide variation both in numerator and denominator values of rate calculations (Purschwitz 1992; Groeneweg 1992; Carstensen et al. 1995; ILO 2000, Franklin et al 2001). The indicator showing the risk of an accident at work used by the European Statistics on Accidents at Work (ESAW) is the incidence rate, where the numerator is the number of accidents at work that occurred during the year and the denominator is the number of persons in employment in the reference population. The division is then multiplicated with 100 000 (Dupré 2001). Accident coverage is not, however, complete in all member states for self-employed persons and family members, which is one factor in the afore mentioned under-reporting. It has been observed that the number of accidents is larger in epidemiological, interview, and questionnaire studies than in the statistics (Eskelinen et al. 1989; Merchant et al. 1989; Taattola 1994, Kaila-Kangas et al. 2000). Moreover, there is a statistical ratio between the numbers of fatalities, injuries, accidents (without injury) and incidents (the 'accident pyramid' or 'iceberg' theory, (Skiba 1979; Heinrich et al. 1980; Groeneweg 1992, HSE 1997)), according to which on the top of the pyramid there are the fatal accidents and on the bottom the most prevalent non-injury incidents. For example, in construction work, which possesses similarities to agricultural work (Aherin et al. 1992), the ratio is 1:56 between over 3-days lost injuries and minor injuries in the United Kingdom (HSE 1997, data acquired with case studies). The ratio for all the other case studies (creamery, transport, oil platform, hospital), excluding construction, was 1:7.

According to Eskelinen et al. (1989), no more than about 20% of the accidents in agriculture remain unclaimed in Finland. However, 65% of the accidents resulting in injury of less than three days incapacity or no incapacity at all were not reported at that time. The most common type of accident that was not reported was injuries with machinery or other objects. According to statistical data from compensated injuries of entrepreneurs (including family members) in agriculture, fishing and reindeer herding in Finland during 1991–2001, only 10% of compensated accidents resulted in less than three days incapacity for work (Tolonen 2002). Kaila-Kangas et al. (2000) noted that about one third of accidents in agriculture did not result in incapacity for work. These results considered together with the pyramid theory leads to the estimation that 10–30% of accidents remain unclaimed. The number of accidents without an injury is added to this.

With regard to fatal accidents in agriculture, there is research to be found for retrospective rates on incidence (e.g., Purschwitz 1992; Browning et al. 1998, McGwin et al. 2000). However, considering the scope of this thesis, rates for non-fatal accidents are reviewed in Table 1. Moreover, altogether nine accident rates cited by Carstensen et al. (1995) and Browning et al. (1998) settle themselves between the extremes of 3 and 166. A striking feature of the rates, noted also by Carstensen et al. (1995), is the great variation. One reason for the difference between the results from sample studies and statistics is presumably under-reporting. Under-reporting in the case of accidents to employed agricultural workers is expected to be lower than that of self-employed. The overall accident rate per 1 000 wage and salary earners together with self-employed persons and assisting family members was 31 in 1998 in Finland, calculated from statistics (Statistics Finland 2002a and 2002b). According to the interview survey of 31 500 respondents, the overall accident rate in Finland in 1998/1999 was 59 (Karjalainen et al. 2000). In comparison, a representative random sample with CATI gave the rate as 91 for all industries (incl. accidents en route to work, Laitinen 2000). Compared to the rates between 69 and 161 in agriculture in Finland, it seems that the accident incidence is higher in agriculture than in all industries on an average.

Reliable and accurate figures about working hours, necessary for calculating the accident rate based on the number of hours worked, are not readily available in Finland. However, Lemola (1988) studied the variation of risks in different agricultural tasks by comparing the number of lost working days due to incapacity for work to the number of working days in a particular work task. He found that, on an average, almost 2% of working days are lost because of accidents. A great variation between the tasks was discovered. With the most dangerous task, moving animals, the share of lost working days was about quadruple the average. Lemola (1988) concluded that the accident rate in agriculture is among the highest in terms of accidents leading to death, but on an average level regarding the accidents resulting in recovering injuries.

Table 1. Review on accident rates in agriculture presented in the literature.

Country	Source	Accident rate (accidents/1 000 persons(*)	Notifications
Finland	this thesis, data Mela 2002	69	incl. fishing and reindeer herding
Finland	Virtanen et al. 2003	91/58	men/women
Finland	Kaila-Kangas et al. 2000	115/112	men/women
Finland	Laitinen 2000	161/138	in 2000/in 1997
Finland	Susitaival & Husman 1994	150	accidents with medical treatment
Finland	Vääriskoski et al. 2000	100	employed stand-ins, medical attention or at least one day incapacity for work
USA, five states	Gerberich et al. 1998	58	all persons living on farms
USA, Iowa	Lewis et al. 1998	104	principal operators
USA, Ohio	MacCrawford et al. 1998	50	principal operators
USA, Oregon	O'Connor et al. 1993	46	all persons >14 years old working on farms
USA, North Dakota	Geller et al. 1990	209	principal operators
USA, Ohio	Napier et al. 1985	163	principal operators
Canada	Brison & Pickett 1991	96	all persons living on farms
Australia, Queens-land	Ferguson 2000	203	all persons living on farms
Denmark	Rasmussen et al. 2000	350	1-year self-registration
European Union	Dupré 2001	75	estimate for 1999, accidents with more than 3 days' absence from work

(* Rates are transformed and calculated to rate denominator 1 000 from original rates in some cases.

Yet, two sources of statistical information of total working hours may be utilised combined for increased reliability of approximation: the Agricultural Census 2000 (TIKE 2003) and the information from bookkeeping farms (Tauriainen et al. 2000, 1 082 farms). The resulting approximation for working hours of farmers, spouses, and other family members used here is 200 million hours per year. Given 6 975 compensated accidents in 2001 (Mela 2002a), the rate for the accident frequency is 35 for one million working hours. In Norway the equivalent rate is reported to be 29 (Reiling 1997); in Sweden 50 in 1987 (Hansson et al. 1989); in Australia 30 (Ferguson 2000), and in the USA 24 (McGwin et al. 2000, Alabama and Mississippi) or 34 (Myers 2001, national surveillance). Rasmussen et al. (2000) reported a markedly higher total accident rate for farmers in Denmark (346). Since the strengths of that research were the intensive and prospective registration of accidents and registration of working hours actually spent in farming (reported by farmers), the question is whether the rates in other studies are underestimated or if there is a greater incidence of accidents in Danish farming. Estimation based on present information suggests mainly the former. The accident rate for employees in all industries was 29 in Finland in 1998 (Seppälä 2000).

As mentioned earlier, there is variation both in numerator and denominator values of rate calculations between different studies and statistics. The amount of exposure to hazards and types of hazards varies between target populations as well due to differences in farming practises, for instance. Virtanen et al. (2003) found that the injury rate for full-time farmers is 46% higher than the rate for all insured farmers in Finland, which may have led to underestimation of risk in injury statistics since only one half of insured farmers are full-time farmers and estimates on injury risk have not taken this into account. Under-reporting related to statistical information is widely recognised, especially connected to minor injuries and branches with many self-employed, and small companies (Merchant et al. 1989; Purschwitz 1992; Taattola 1994; Forastieri 1999; HSC 2001, Thelin 2002).

In conclusion, it can be stated that, compared to all industries, agriculture has a lower level of safety globally. Considering the research needs, fatal accidents are relatively well-documented, but the non-fatal are not, generally due to insufficient insurance and surveillance programs for self-employed farmers (Rautiainen 2002). In terms of non-fatal accidents, Finnish agriculture does not seem to be clearly safer than agriculture in other developed countries. Compared to working life in general, the incidence of non-fatal accidents seems to be higher for agriculture in Finland. In Finland all farmers are covered by workers' compensation, the population is well-defined and accident information is available, which offers a unique possibility for safety research.

Recent global trends

Worldwide, the progression of accident rates is neither clear nor consistent among the areas of comparison. In the EU, accident rates for agriculture, hunting and forestry have increased during the 1990s, in contrast to the rates in most other branches of industry which have decreased (Dupré 2001, accidents with more than three days' absence from work). Similarly, the ILO (2000) reports that globally accident numbers rose for agriculture in the 1990s in contrast to other hazardous industries in which they decreased. In Great Britain, HSC (2001) reports that the rate of reported non-fatal injury in agriculture has oscillated with no apparent trend during the past six years. However, in the 1990s, the rate of non-fatal injury had generally fallen (HSC 2001). During the past decade in the US, the fatal injury rate has remained high and there is no clear indication whether the non-fatal injury rates for farmers have changed, according to Rautiainen and Reynolds (2002). Between 1993 and 1998, only in the dairy industry was the increase in injury rates statistically significant in Australia, compared to other agricultural branches with varied trends (Ferguson 2000). For the period 1985–1995, a significant increase in farm fatality rates was also noted in Australia (Day 1999). Thelin (2002) reports an increasing trend in fatalities in farming in Sweden, too.

For Finland, there are no recent published analyses for accident-rate trends in agriculture. The conclusion as to the development of safety in agriculture globally is that recent rising trends are alarming, especially compared to other industries. However, in the long term, the overall development of safety standards has been mainly positive.

Characteristics

The scholarly research on agricultural occupational safety with respect to accidents has revealed several characteristics, causal or descriptive, related to the incidence of accidents. The nature of risk factors in agriculture is complex since farmers are exposed to a wide variety of hazards in their work (ILO 2000, Park et al. 2001).

Perhaps the two most common accident factors are the farm environment (e.g., tractors without roll-over protective structure, types of farming operations) and the personal, sociodemographic characteristics of farmers themselves (e.g., age, gender) (MacCrawford et al. 1998; Browning et al. 1998, Virtanen et al. 2003). Moreover, a group of factors describe the outcome of an accident and injury (e.g. the nature of the injury) rather than *a priori* causes. Not all the research has been limited to the farm, farmer, and accident when seeking explanatory factors affecting the safety of farming operations. There have been studies from the perspective of social science, in which the greater context of farming and the farmer as a part of society has been explored (Napier et al. 1985; Geller et al. 1990, Day 1999).

Factors in the groups discussed above have been utilised earlier mostly with descriptive statistics and with bivariate techniques. Recently, multivariate methods with the goal of finding predictive power have been used increasingly (Napier et al. 1985; Zhao et al. 1995; Gerberich et al. 1998; Lewis et al. 1998, McGwin et al. 2000).

Machinery in general is repeatedly discovered to be one of the most important sources of hazards in agriculture (e.g., Browning et al. 1998; Gerberich et al. 1998; ILO 2000; McGwin et al. 2000, Rasmussen et al. 2000). Several studies indicate that farm accidents are not randomly distributed throughout the farming industry and population (e.g., Tupi & Vohlonen 1983; Geller et al. 1990; Zhao et al. 1992; Browning et al. 1998; Lewis et al. 1998; ILO 2000; Park et al. 2001, Virtanen et al. 2003). Details of these findings are discussed below.

The most outstanding feature of occupational safety concerning farmers and agriculture has been the high rate of mortalities related to tractors. The safety issue of tractor overturns has been known since the 1920s (Arndt 1971). The problem has been a target of extensive research and the mandatory introduction of roll-over protection structures in the 1950s in some countries on new tractors, and later in some cases on old tractors, has significantly decreased the number of tractor-related fatalities in those countries (Arndt 1971; Gilfillan 1979; Karlson & Noren 1979; Ross & DiMartino 1982; Goodman et al. 1985; Erlich et al. 1993; Springfeldt 1993; Springfeldt et al. 1998; Thelin 1998, Franklin et al. 2001). Nevertheless, both the fatal and non-fatal accident probability connected to the use of agricultural tractors seems to remain high, especially in countries without mandatory requirements for ROPS on all tractors (Myers, et al. 1998; Day 1999; ILO 2000; Gerberich et al. 2001, Rissanen & Taattola 2002). In-depth studies into specific classes of tractor accidents have been recommended (Langley et al. 1997). Specifically, design characteristics of the tractors associated with accidents that occur during mounting or dismounting activities are suggested as targets of investigation (Gustafsson et al. 1991; Hammer 1991, Lee et al. 1996).

Furthermore, in addition to tractors, animals constitute a significant source of hazard. Work with large animals and herds of animals involves high risk because of sudden animal movements, for instance, and their potential to cause severe trauma (Hansson et al. 1989; Boyle et al. 1996; Browning et al. 1998; McGwin et al. 2000; Rasmussen et al. 2000; Gerberich et al. 2001, Park et al. 2001). It seems that more knowledge about animal behaviour is needed to secure safer work practices. This is emphasised by the developing production technology involving animal tending, for instance, in the case of voluntary milking systems.

On farms, the operation environment of production is exceptionally varied. Farmers are exposed to all the seasonal weather conditions with extreme temperatures, varying lighting conditions, and precipitation. The work environment alternates from outdoor terrain to interiors of large and small production buildings with animals and high bulk product stores with a variety of biological and chemical materials in them. Further, long hours are spent on driver seats of tractors, other self-propelled machinery, and vehicles. These conditions combined with the extensive need for transport, locomotion, and occasional hard physical labour, contribute to a large number of falls on level ground or from a height (Napier et al. 1985; Hansson et al. 1989; Brison & Pickett 1991; Carstensen et al. 1995; Browning et al. 1998, Stave & Törner 2000).

Another typical feature of agricultural production that can produce hazards is the great variation in tasks within and between farms and production types. Task demands and hazards involved vary widely during the workday and between farms. Tasks include, for instance, construction work, machinery repair and maintenance, veterinary procedures and crop processing and packaging, to name just a few. Since production is dependent upon the biological and seasonal cycles of nature, the intensity, pace and the length of the workday in operations vary accordingly.

The work force meeting these challenges in farming has unique characteristics compared to most other industries. In most countries, production is still based on family-owned and operated enterprises or family farms of different sizes. The principal operator may have a secondary occupation. Family members younger and older than the conventional work force commonly take part in farming operations. A striking feature of accidents in agriculture is the high involvement of both young and old, outside the normal age range of the work force (Merchant et al. 1989; Zhao et al. 1995; Browning et al. 1998, Ferguson 2000). This issue has been the subject of research and intervention programs as well, especially regarding children and adolescents in the USA (National Committee 1996; Osorio 1997, Sebille et al. 1997). The classifications of age differ from study to study making it almost impossible to give any precise definitions for “the old” and “the young” and compare various studies precisely (Purschwitz 1992). There is support both for the young (Geller et al. 1990; Carstensen et al. 1995; Zhao et al. 1995; MacCrawford et al. 1998 Gerberich et al. 2001) and the old (Erlich et al. 1993; Zhao et al. 1995; Gerberich et al. 1998, Pickett et al. 2001) having an elevated accident probability. There has not always been correction against the differences in exposure, caused by different amounts and types of work. Moreover, both the nature and cause of accidents vary in some degree between the cohorts of the young and the old (literature cited above). For example, it has been suggested that older farmers tend to have a greater proportion of fatalities, whereas the highest probability of non-fatal injury is among younger farmers (MacCrawford et al. 1998, Myers et al. 1998). In conclusion, it is shown with some exceptions (McGwin et al. 2000, Park et al. 2001) that age, especially in the extreme classes, is a factor with differentiating power for accident probability. However, age as such is not the explanatory factor, but rather a proxy for many types of factors related to impaired working capacity, for instance deficient hearing or sight (Browning et al. 1998, Zwerling et al. 1998). In terms of the outcome of an accident, age may affect vulnerability and recovery.

For entrepreneurs in agriculture formal education may be inadequate and government regulation and supervision of work is, in most countries, minimal or nonexistent. Working ability may be decreased due to impaired health, physical deficit, or intoxication (Browning et al. 1998; MacCrawford et al. 1998; Lewis et al. 1998, Rissanen & Taattola 2002).

All these features result in characteristics of work that vary from day to day and from farm to farm. This multiform nature of production is manifested in a wide variety of hazards and challenging multivariate modelling of accident causation. According to the ILO (2000), occupational accidents in agriculture are mainly due to physical, mechanical, ergonomic, chemical, and biological hazards. Operations involving increased variation in both tasks and circumstances as well higher numbers of disturbances (e.g., machinery breakdowns) have been generally noted to have a higher accident probability (Saari & Lahtela, 1981; Salminen et al. 1991; Backström & Döös 1997; Varonen 1997; Kjellén 1998, McGwin et al. 2000). One possible explanation for this may be too great an information load involved (Saari 1984, Salminen et al. 1991).

In the case of agriculture, effects subsequent to the injurious event can be divided into two closely associated domains: those that describe the outcome on an individual and those that describe consequences on production and enterprise. These two intertwined issues, one of each group, are discussed: severity of injuries and cost impact of accidents. In comparison to other industries, an accident in agriculture appears to result in a more severe outcome (Taattola 1994; Laitinen & Rantala 1997; Ojanen et al. 2000, Seppälä 2000). The average incapacity for work for compensated accidents resulting in incapacity in Finland during 1986–2000 has varied between 27–32 days for agricultural entrepreneurs and insured family members. The average calculated for all compensated accidents has varied between 24–29 days during the same period (Pihkala 2002, terminable and permanent settlements included). The average incapacity for work resulting from injurious accidents in agriculture is reported to have the following durations in days: 11 (Ferguson 2000); 16 (Napier et al. 1985); 23 (Taattola 1994); 24 (Rautiainen 2002, short-term disability), and 29 (Hansson et al. 1989). However, when using the average duration of incapacity for work as a measurement of severity, the injury definition, representativeness of the injury population in question and distribution should be clarified. The average incapacity for work due to an occupational accident was 12 days in Finland in 1997 (Seppälä 2000).

Besides incapacity for work, accidents have other and related undesirable consequences to the functioning and recovery of the agricultural enterprise (Monk et al. 1986; Carstensen et al. 1995; Lee et al. 1996; Cole et al. 1997, Gerberich et al. 2001). Unfortunately, scholarly research on the costs and other consequences of accidents is limited in this field (Tormoehlen & Field 1995; Zhao et al. 1995, Rautiainen 2002). It has been reported that in several industries the hidden, uninsured costs are multifold to the insured costs (HSE 1997). For example, the immediate disturbances in operation and variable costs of medical treatment and damaged property are the obvious consequences after an accident. Delayed and long-term consequences and fixed costs are not so easily detected or calculated. The social, less obvious areas affected might include personal mental health, family and domestic activities, labour relations, and community affairs (Dembe 2001). Nevertheless, indirect costs might be the major financial losses in agriculture in Finland (Seppänen 1990), as detected with other industries as well (HSE 1997, Kuusela et al. 1997). According to Monk et al. (1986), small farms with a small labour force were inclined to greater delay costs (e.g. timeliness penalties) and delay-avoidance costs than larger farms. Damage to property was the predominant cost element in Great Britain. Nevertheless, Zhao et al. (1992) and Rautiainen (2002) suggest that indirect costs from property damage are not very significant. The causes of this disagreement may derive from different target populations, research methods, and definitions of property damage.

A case study of costs related to agricultural accidents with permanent disability (paralysis of the lower limbs) revealed a total loss of $446 587 incurred by the injured person and his/her family (Tormoehlen & Field 1995). In the study of serious accidents (incapacity more than 30 days) in agriculture, Stave and Törner (2000) formed a cost analysis for a typical case. The sample calculation was based on a machinery-related accident that led to incapacity of 83 days. The result showed a total loss of 14 652 euros. The most important loss resulted from the lost income of the substitute worker (family member). The second most important expense item was the timeliness costs. In this case, only 33% of the total loss was compensated by insurance. Similarly, it is presumed that, depending on the case, only a part of accident costs burdening the enterprise is compensated to the farmer by the mandatory insurance system in Finland. However, the costs of medical and hospital care, medicines, and any travelling expenses incurred are compensated in full (Mela 2002b). In the event that the accident or illness renders the victim incapable of working, a daily allowance, pension, or rehabilitation expense is paid. According to Rautiainen (2002), in 1996 the total insurance cost in agriculture was 23,5 million euros in Finland, which was 2,5% of the insured farm income. The mean cost of accident claims with permanent pensions included was 1 340 euros. Incident types with high cost included slips and falls and incidents caused by being struck by or run over by machines and animals. The most costly outcomes included internal injuries, amputations and bone fractures (Rautiainen 2002).

In conclusion, by simplifying the typical features of agricultural accidents, the following aspects can be summarised from the literature and discussion above: machinery, animals, or falls are often among the immediate, proximal accident factors. The deviations resulting from the unstable characteristics of production and its environment (e.g., icy terrain in winter) may also explain the emergence of several other hazards. Injuries are often severe and affect work capacity, enterprise profitability, and functioning.

2.4 Safety management in agriculture

At present many farmers seem to utilise intuition, experience and commonsense in their approaches to planning and decision-making, rather than quantitative methods of management (Miller et al. 1998, Nuthall 2001). However, the term management has its origins in agriculture; it originally included the meanings of the working or cultivation of land and the process of manuring, among others (Oxford English Dictionary 2000b). In common parlance the word management also connotes care, charge, conduct, handling, intendancy, running, superintendence, and supervision (Merriam-Webster 2002). The concept of management appears to have evolved from the narrow meaning given in agriculture to a more extensive term.

In the economic and management disciplines the word management has several meanings as well. Drucker (1999) argues that the scope and definition of management both as a discipline and as a practise has to be operational, focusing on results and performance across the entire economic chain rather than being based on legal or political assumptions. His (op.cit.) suggestion for the basis of the new paradigm and definition is that management is the specific tool, the specific function, or the specific instrument that makes the institution capable of producing results outside of itself. According to Parnell et al. (1999), the terms management science, systems engineering and operations research refer to the same process, which is the application of systems analysis to gain a better understanding of a problem and make decisions that increase profit. These definitions are complementary to each other and therefore, management is referred to in compliance with both these definitions here.

In order to control accident risks, risk management is needed. Risk management involves the systematic application of management policies, procedures and practices (SFS-IEC 60300-3-9 2000). A tool and concept for this is safety management, which means an overall system developed to ensure that safety activities are properly planned, effectively implemented and followed up (Kuusisto 2000). In the case of agriculture, which is a branch largely based on self-proprietorship in small family units, the management of businesses is a key issue when planning for safety interventions and safety promotion. Occupational safety and health in agriculture is a function of management

(Murphy 1992). Scientific contributions on applications of formal safety management theories or practises in family farming are not available, although it has been noted that risk management principles are not widely applied in agriculture (Ferguson 2000). Therefore, the concept of safety management is dealt with here.

Safety management is an overall system that involves proper planning, organising, implementing, and following of safety activities. Its primary aim has been to intervene in the accident causation process and break the chain of causation. This includes detecting or preventing both visible and latent hazards (Booth & Lee 1995, Kuusisto 2000).

The examination of accident risks here earlier has made it evident that agricultural production involves a multitude of risks to the health of the farming family. Nevertheless, accident risks are not the only source of uncertainty. Farming can be considered a high-risk business in various dimensions (Jolly 1983; Benson 1999, Sonkkila 2002). Managers in agriculture must often make decisions although they are uncertain about conditions in at least three main areas: about current state of nature and weather, biological and physical systems, and inherently random processes (Thysen 2000). Additionally, developing production technologies are important sources of uncertainty. Thus, success in safety and in business in general places high demands on the decision-making processes of management.

Psychological and economical approaches to decision-making are not discussed here separately. Some implications of decision-making are presented in the contexts of management and later in the intervention and discussion sections of this text. However, decision-making and management can be seen as synonyms (Sonkkila 2002). The leadership dimension of the management concept is not discussed here either, since in the practise of management in family farming the problem of managing employed people is not often relevant in Finland today (Timonen 2000).

According to Rasmussen (1997), safety depends on the control of work processes. Health and safety management is seen ideally as an integrated part of overall management. Furthermore, environmental and quality issues have been introduced to management systems and models. Integrated systems are referred to as SHEQ (safety, health, environment and quality) (Heinrich et al. 1980; Lahtinen et al. 1992; Kylmänen et al. 1994; Reason 1997; BS 8800 1998, Kuusisto 2000). According to the British standard on guidance and recommendations for health and safety management systems (BS 8800 1998), there is already a comprehensive legal framework for occupational health and safety, which requires organisations to manage their activities in such a way as to anticipate and prevent circumstances that may result in occupational accidents or ill-health. The standard (op.cit.) seeks to improve the occupational health and safety performance of organisations by providing guidance on how the management of occupational safety and health may be integrated with the management of other aspects of business performance. The three purposes listed are: minimising risk to employees and others, improving business performance, and assisting organisations in establishing a responsible image within the marketplace. The safety, health and environmental burdens placed on employees by agricultural processes, machines and chemicals over their whole lifespan have been raised as concerns in both developing and developed countries (Saran 1997).

Managing safety and health is a part of managing uncertainty and risk. Rasmussen (1997) considers risk management to be a control function focused on maintaining a particular hazardous, productive process within the boundaries of safe operation. Risk management and safety management are overlapping concepts. Strategies, and methods available to risk and safety management are largely shared (Heinrich et al. 1980). Jolly (1983) argues that highly simplified, risk management involves increasing the information base on which decisions are made. It has been stated that since practically all actions undertaken by a farm manager are subject to risk, farm management equals risk management (Jolly 1983). Planning, implementing, and controlling are the three broad functions of management. Risk management is an important component of the planning and implementing functions. It involves understanding the sources of risk, identifying and evaluating the potential impacts of specific risks, and understanding and applying specific risk management strategies and tools (Jolly 1983, Benson 1999).

Accidents and disturbances are failures of system performance. They are known to create costs and may result in inferior product quality, among other things (Heinrich et al. 1980; Liukkonen 1989; Lahtinen et al. 1992, Kylmänen et al. 1994). Controlling accidents and quality errors requires similar strategies. The same faulty practise is involved and the reason for the existence of the fault is similar, according to Heinrich et al. (1980). They (op.cit.) argue that the causes of accidents are also the causes of other operational errors and the same methods that control production and other managerial problems will also control accidents.

Op De Beeck and Van Heuverswyn (2002) have suggested a number of factors in the ever-changing world which have important implications for the management of safety and health. These factors include changes in technology, changes in work pace and workload, and the growth of subcontracting. Such developments concern agriculture as well, as discussed earlier. In terms of accidents, the interaction between economic failure and unacceptable workload must be taken into consideration in risk management (Rasmussen 1997). According to Rasmussen (1997), the present competitive environment forces managers to make decisions based on short-term survival and financial criteria rather than on long-term criteria concerning safety, welfare, and environmental effect. At the same time, the pace of technological change is much faster than that of management structures.

Howell et al. (2002) have presented a new approach to construction safety based on the work of Jens Rasmussen. Construction work embodies some characteristics similar to agricultural work, such as varied work and exposure to the forces of nature. Construction work is among the most hazardous work as is agricultural work. Simplified, Howell et al. (2002) suggest that in these circumstances, applying better planning can enhance safety when pressures push people to work near the boundaries.

With regard to safety management in agriculture, one can reasonably conclude that general or safety management practises often are not applied. However, one can extrapolate from the literature discussed above that such methods would be applicable to the current safety and quality policy needs of agriculture and they should be brought into the discourse. Management and safety management appear to be logical channels for safety interventions.

2.5 Summary of the literature review

Safety must be defined together with the concepts of risk and hazard. The state of safety is not directly measurable, but negative outcomes, such as accidents, are easier to quantify than the more enduring presence of safety. It seems worthwhile to include management issues into research on accidents in agriculture. Combining the theories on the organisational accidents and individual behaviour could be beneficial for further success in safety research and promotion.

Change in agricultural work has been largely characterised by developments in technology, society, and global economics. In the industrialised countries, the work in agriculture will be more dominated by cognitive, information-intensive business management than by work characterised by physical activities. Both positive and negative implications for the well-being of the work force will result. The challenge for the researcher is to present solutions for production which will keep farming as an attractive occupation.

In general, safety in agriculture in terms of the accident rate seems to be worse than in other industries in Finland. Comparing safety statistics to other industrialised countries, we find differences due to the sector of safety. However, overall Finnish agriculture does not seem to be notably safer in terms of non-fatal accidents. For Finland, there are no published analyses for accident rate trends for agriculture. Abroad, several rising trends have been reported recently in contrast to the positive developments in other sectors. However, the long-term development of safety has been positive.

Machinery, especially tractors, animals, and falls are often mentioned as the most prominent factors related to accidents in agriculture. The fluctuating nature of the work and the work environment result in the emergence of several hazards. Injuries are more severe on an average in agriculture than in other industries in general.

Safety management approaches are not often applied in safety research on farming. However, such methods can be used to explain and develop safety in agriculture, keeping in mind the notions in relation to organisational accident theory and expected changes in agricultural work.

3 Aims of the study

To gain sufficient understanding of accident causality in agriculture, and to promote tractor safety, tractor accidents were chosen as the target for case studies. The review on accident theories and safety management pointed to the relevance of management in accident causation and safety promotion. Consequently, the aim was set to test if factors related to farm management can be found and utilised for an intervention concept.

The specific aims were to:

1. Examine the trend, nature and causes of accidents in agriculture, and particularly the nature and causes of tractor accidents (summary, I, II, III);

2. Develop a method for the examination of accident causation (summary, I, II, III, IV);

3. Examine management in relation to safety in agriculture (IV), and

4. Identify methods of accident prevention (summary, I, II, III, IV).

4 Materials and methods

Subsequently, the methodological approach, methods, and materials employed in this thesis are briefly presented. The methods applied by the Finnish Institute of Occupational Health in article III are not discussed here.

4.1 Methodological approach

An important science-based approach to occupational accident prevention is the public health approach (Stout & Linn 2002). It is based on the assumption that an accident is a health problem and as such can either be prevented or its consequences mitigated (Smith & Veasie 1998). The public health approach is usually multidisciplinary, based primarily on scientific methods of epidemiology, among others (Linn & Amendola 1998; Smith & Veasie 1998, Stout & Linn 2002). Epidemiology is the study of the distribution and determinants of diseases and accidents in a population (Smith & Veasie 1998). The phases of the public health approach are:

1. the identification, characterisation, and description of accident cases, hazards, and exposures;

2. the in-depth analysis of specific accident problems in specified worker populations in order to identify, quantify and compare risk and causal factors;

3. the identification and development of prevention strategies and interventions;

4. the evaluation of preventive strategies in laboratory and field experiments, and

5. the communication of information on risk and the development of strategies and programmes for reducing risk and preventing accidents (Linn & Amendola 1998).

In this thesis, this approach has been applied with the distinction that the fourth phase and part of the fifth phase were not within the scope of the work. Other scientific bases for this research are in agricultural engineering and safety science. Because both of these applied sciences are rooted in other sciences and the nature of the problem is multidisciplinary, other sciences are touched upon as well. Safety science and agricultural engineering are related methodologically; both utilise the systems theory approach and ergonomics. The object for research in both disciplines is often related to the functionality of production systems and interactions in the system (see also Wilson 2000). This is also the case in this research.

Both qualitative and quantitative approaches are utilised. The applied research method is epidemiological and cross-sectional in design, and includes statistical data, survey material, and case studies. The newly-developed method includes combining statistical and case study methodologies in the guidance of a new applied, theoretical approach in the context of sole entrepreneurs.

4.2 The structure of the study

The structure of the work is described in Figure 3. The study began with a literature review (I, II, III, IV, summary). It was followed by case studies of tractor accidents and a mail survey of control farms (I, II, IV). Accident statistics were utilised especially in articles I, II, III and in this summary. The analysis of statistical characteristics was made with conventional direct distributions and using log-linear models (I). Univariate statistics were used to document the incidence of farm accidents among the sample populations. Bivariate cross tabulations between the incidence of farm accidents and the independent variables are presented to examine the strength and direction of the assumed relationships (II, III). Poisson regression modelling was used as the primary method in the study of management and risk factors (IV). Variables related to management are described in appendix 1, since there was not enough space for detailed variable descriptions in the article IV. Inclusion and explanation of predictive factors chosen to multivariate analyses were based on logical and biological plausibility between the accidents and potential hazards (Browning et al. 1998) as well as to the utilised organisational accident theory.

In Figure 3, the relations between the aims and materials are not strictly restricted only to those relations described with arrows; rather they are the main influences. Double-headed arrows mean that the literature survey was utilised both in determining the aims and as a source in the more focused review. Similarly, methods without the indicating arrow may relate to materials in a limited way.

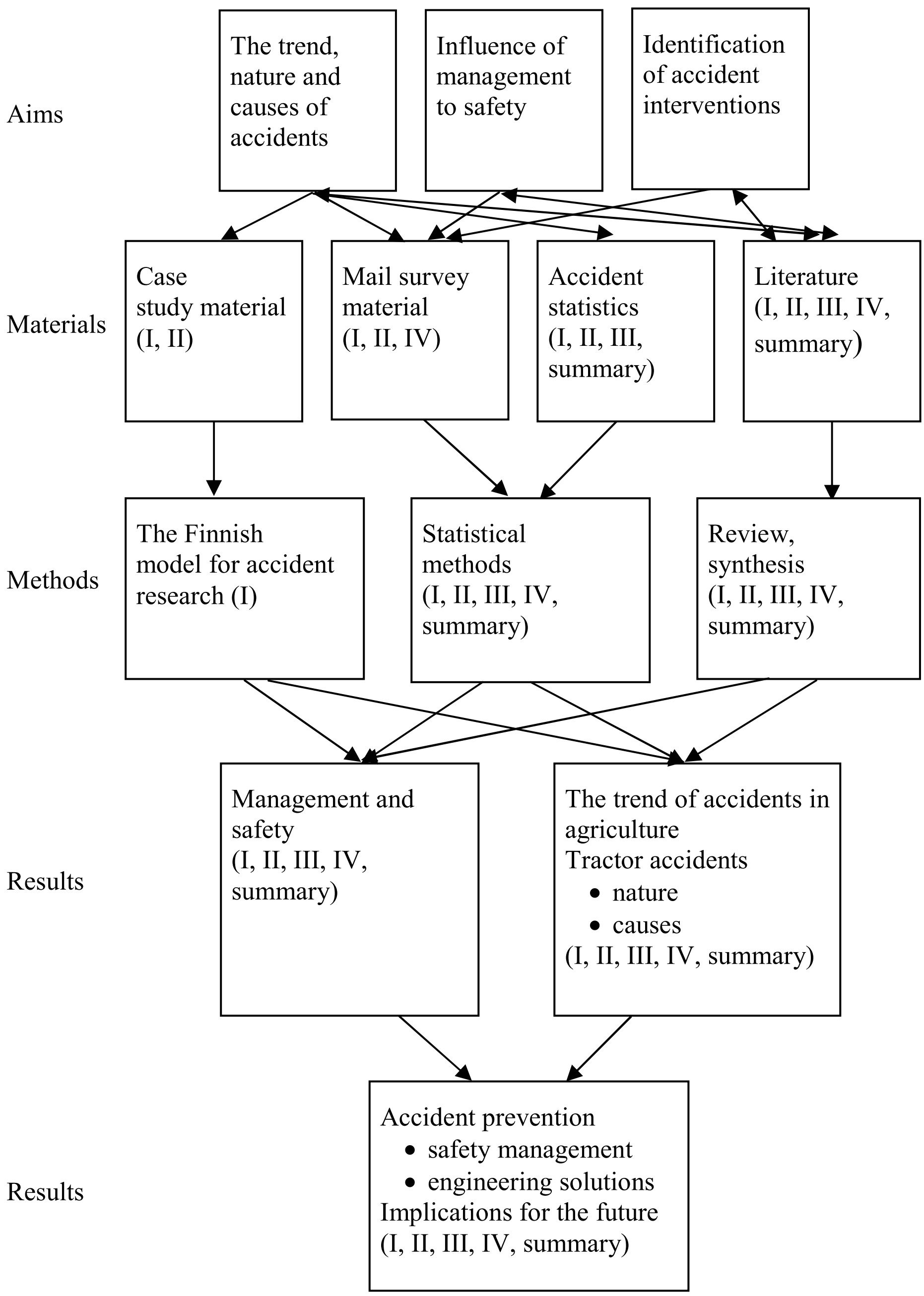

Figure 3. The structure of the study. Roman numerals in the boxes refer to original articles; the text "summary" refers to this text in the thesis.

5 Results

5.1 Accidents trends in agriculture

Since there are no trend analyses available for accidents in agriculture in Finland, statistical data (Mela 2002a) were used to establish major trends. During the period 1991–2001, the accident rate for compensated accidents of agriculture, fishing and reindeer herding in Finland decreased from 84 to 68 per 1 000 entrepreneurs per year. Calculated from the statistics of Mela (2002a) (including insured family members aged 15–65 years), the downward trend of the rate was slight, 2.2 per year, but statistically highly significant (SE=0.32, $p<0.001$).

During the given period, the share of insured fishers and reindeer herders was only 2.3% of all of Mela insured (Mela 2002a). Consequently, it can be assumed that the trend is largely due to a change in the accident rate of farmers and their family members, particularly when considering that the decrease in the fisher and reindeer herder populations has been close to that of farmers. When analysing the accident rates divided to accidents with less than three days incapacity for work and to more severe accidents, I note that the decreasing trend during the period 1991–2001 is based to the decrease in accidents with at least three days incapacity for work (data: Tolonen 2002). Linear regression analysis reveals a statistically significant decrease in accidents with at least three days incapacity for work (SE=0.20, $p<0.001$), whereas the decrease in the rate of accidents with less than three days incapacity for work indicates a statistically nonsignificant trend (SE=0.08, $p=0.11$).

5.2 Tractor accidents

Nature of tractor accidents

In Finland, tractors account for 3–4% of all compensated accidents (I, II). Tractor accidents are not evenly distributed throughout the year. In May, the relational share of accidents is the highest. The rush due to the short seeding time in the spring and consequent human errors may explain this. In all, May, June, July, and August had a 68 % share of the accidents (I).

The majority of the tractor accidents occur when the operator is using the access path to or from the cab, or when hitching or unhitching implements. The share of accidents related to access path usage is more than 30% for all accidents associated with the use of tractors in agriculture (I, II, III). The share of accidents during hitching or unhitching implements is similar (I, II). The average incapacity for work was 26 days for all tractor accidents (I, II) and 33 days for accidents that occurred during access path usage (III). However, the distribution of incapacity for work is skewed for access path accidents; the median was 14 days incapacity for work (III). The most common consequences of tractor accidents were strains and sprains of the lower limbs which mostly resulted from the use of the tractor's access path. Hitching and unhitching implements mainly resulted in contusions of the limbs (I, III).

There are strong differences in the accident frequencies according to the injured part of the body. In 55% of accident cases, the consequence was an injury to the lower limbs (from hip to ankle, feet and toes not included). The second most common injured body part was the back (muscular tissue) and spinal column (13% of accidents). The third most common injured part of the body was the upper limb (from shoulder to wrist, 9%). The high share of injuries in lower limbs and back are presumed to be consequences of jumping out of the cab. The most typical consequence of an accident on the access paths was a strain or sprain. Contusions (including *bursa, rotator cuff, ruptura supraspinatus* and tears of *menisci*) were the second most common injuries (17%), and the third most common was fractures (15%). These three injury types accounted for 96% of all injury types in the single-year statistics. When the type of injury and injured part of the body were cross-tabulated, it was proved that 48% of access path accidents were strains and sprains of lower limbs. This leads to a conclusion that a typical sequence of an accident may start with jumping, letting oneself drop down, or slipping or tripping during exit from the cabin. Falling or some other sudden movements connected with uneven ground leads typically to sprains or strains of the ankle. These cases also lead to the highest total number of disability days. The distributions of injured part of the body and type of injury interpreted together with descriptions of accidents reflect the detail and overall defects of access path ergonomics (III).

More accidents in relation to the number of registered tractors were found in the eastern and central parts of Finland than in the southern and southwestern regions, where the share was accordingly smaller than on the average. This unevenness may be due to the relatively large number of machines in relation to arable land and the less favourable production conditions in northeast Finland, because it has been shown that the number of accidents has a higher correlation with the number of machines than with the area of arable land (I, IV).

Causes of tractor accidents

The accident probability with a tractor is influenced by how much the tractor is used. A comparison of the tractors showed that those involved in accidents were newer and they were used more frequently than all tractors on the farms of this study (II). The condition and safety features of “accident tractors” were better than those of tractors in general. However, insufficient or inadequate safety equipment contributed to the accident in 14% of the cases. In

40% of the cases, access to the cab was in an unacceptable condition. In access-related accidents, however, the condition of the accesses was not significantly worse than accesses of other tractors involved in accidents. In most of the cases investigated, the condition of accesses did not contribute to the accident directly. Instead, bad access was assessed to contribute indirectly by affecting the way the operator acted when dismounting the cab (II). The targeted study presented in article III, shows examples of failures in design, which logically contribute to accident probability. These failures include the detected gaps in the three-point contact during the movements and the flexible lowest step (III). The so-called three-point contact means that the user has at least three of the limbs supported at any given time during the movement.

The causes for tractor accidents include the varying and seasonal nature of farming and the characteristics of farmers in addition to and in relation to the safety standards of a tractor. The work situation was new for 32% of casualties and long task intervals were involved in 30% of cases (I). Tractors were deemed defective in 26% of the cases (I). As noted above, the study of access path safety (III) revealed that less-than-adequate design might manifest itself in hazardous, accident-contributing features. The health of farmers was poor in 78% of the cases (I). The awareness of operators about safety issues was not always sufficient. In 68 % of the cases, the hazards were unfamiliar to those who experienced casualties (I). Furthermore, traditionally unsafe working methods and habits were a causal factor in 53% of the cases and in more than 90%, safer methods or habits would have helped in avoiding the accident (I). A comparison of human behaviour factors of tractor accidents to accidents in ten industries revealed that those involved in tractor accidents took safety measures to avoid known hazards less frequently (II).

5.3 Management and safety

The prevalence and severity of accidents and disturbances in a given situation is one indicator of the quality of management. Variables used in this research to indicate the quality of management and accident risk included delays in work, the number of machines, musculoskeletal disorders, and stress measured by exhaustion (IV). These represent the outcome of the manner of production and operations that the organisation has selected. For instance, farmers can choose, depending on farm type, from alternatives for mechanising operations, which determine the number of machines. Health problems and exhaustion reveal problems in work organisation as well, which are naturally related to personal physical and mental characteristics.

The results suggest that there are discernible patterns that distinguish high-risk farms from low-risk farms in terms of accident rate. Specifically, farmers reporting high numbers of machinery and musculoskeletal disorders appear to have a higher injury rate (adjusted RR=2.34, CI 1.27–4.31 and adjusted

RR=1.75, CI 1.14–2.69). Delays in work and exhaustion were both statistically significantly more common in crude analysis among farmers reporting more accidents (IV). These findings seem to support the hypothesis that the quality of farm management has an effect on the safety standards of a farm.

Better education should be expected to correlate positively with better safety management. In this study, vocational education was not shown to have a significant effect on injury risk. Although it was not possible to determine why education did not influence the incidence of injuries, one should consider the possibility that the result may be explained by a lack of material or insufficient focus on management and safety issues in education (IV).

The current competitive environment in agriculture may force managers to make decisions based on short-term survival and financial criteria rather than on long-term criteria concerning health, for instance. Furthermore, since the pace of technological change is much faster than that of management structures, success in safety and in business in general places high demands on the decision-making processes of management. Moreover, in a small enterprise like a family farm, management quality is highly dependent on the individual characteristics of the principal operator of the farm. At the moment, the mental demands of farm management, particularly on farms suffering economic hardship, may exceed the capacity of many farmers to manage without symptoms that lead to increased safety risks (summary, IV).

6 Discussion

6.1 Evaluation of the methodology

There was not a single method readily available to resolve the research questions expressed in this study. Therefore, a group of methods, partly modified for this study, were unified to accomplish the research task. Below, the major methods are first discussed separately and in the end of the chapter, as a whole.

Case studies are the only detailed way to acquire information about accidents (Borghoff 1987, Livingston et al. 2001). In order to gain in-depth knowledge about accident causation, case studies were made according to the Finnish accident research model (I, II). It is based on systemic and organisational paradigms, which were the adopted viewpoints of this study. The reliability and validity of case studies in accident analysis is subject to discussion (Hoyos & Zimolong 1988; Weegels 1991, Wagenaar & van der Schrier 1997). Bias between researchers is possible when identifying accident factors and classifying them. Since the writer made all the case studies, the bias between cases is not an issue here. However, possible comparisons to other studies must be made with caution. Moreover, case studies are not to be generalised from one case to another, rather to theory (Yin 1994). The validity of the results was enhanced with data and method triangulations (Yin 1994, Glasscock et al. 1997). In addition to personal observations during case investigations, a separate mailing of self-report survey forms was used. Questions on the form dealt with the same accident factors (e.g., machinery, work methods, person), as did the case interviews. In aggregate, the method was found to be useful in accordance with Tuominen and Saari (1982), Hakala (1989) and Seppänen (1995). Based on the discussion above, it is suggested, that an acceptable level of reliability and validity of identifying and classifying accident factors was achieved in this study.

The epidemiological techniques (descriptive and analytic) used in this thesis have demonstrated utility when identifying hazardous work situations, defining accident causes and designing and implementing preventive strategies (Goodman et al. 1985, Sorock & Courtney 1997). The survey material was obtained partly via self-reporting, partly with interviews (I, II, IV). A structured form was developed and utilised. The target population was the active farming population in Finland insured by Mela. A stratified random sample methodology was utilised. Content validity, i.e., whether or not the questionnaire measured all aspects of interest (Robson et al. 2001), was established by using experts in instrument development.

With statistical analysis, it is possible to determine essential areas for closer analysis (Skiba 1979). Mela provided the materials used in this thesis, except materials for the survey and the case studies. Although the factors in the Mela statistics describe the outcomes of accidents rather than causes, log-linear modelling of accident data proved to be useful and contributed to an understanding of the nature of tractor accidents (I, II), as reported by Hammer et al. (1986), too. Chi-square tests were used related to the nature of accidents on access paths (III) and Poisson regression modelling with management related accident factors (IV). A linear regression of accident trends was performed (Chapter 5.1). These methods proved to be applicable for the purposes of this research. Statistical data is regarded to be representative for the population in agriculture, although the proportion of unclaimed injuries is 10–30% (summary, Eskelinen et al. 1989). Statistical data was utilised mainly in descriptive analysis. The reliability of the data is regarded to be sufficient for that purpose because the coding process has been a target of quality work in Mela (Rautiainen 2002).

In order to operationalise the organisational accident theory, information of various magnitudes was needed. Accident statistics do not provide information on latent accident factors and case studies are too resource-intensive to achieve data of an epidemiological scale. The solution was to combine these approaches so that a comprehensive picture of the trend, nature, and causation of accidents was achieved. This approach is similar to the public health approach (Linn & Amendola 1998), but in this thesis, there was the further question of examining the theory of organisational and management issues in relation to safety. There were no comparable studies available for the evaluation of reliability and validity. However, the Poisson regression modelling of the case-control data proved to be useful.

6.2 Evaluation of the results

Accident rates and trends

The results of Rautiainen (2002, monthly accident rates 1990–2000 by interrupted time series method) confirm the significant reduction in the accident rate. However, Rautiainen (op.cit.) also reports increases in some severe accident categories. A separate trend analysis was also made in this thesis for accidents with over and under three days incapacity for work. Minor accidents indicated no statistically significant trend, whereas accidents with at least three days lost did show a significant decrease. It is feasible to assume that the decrease in accident incidence of minor injuries may remain concealed since a large share of minor injuries remains unclaimed and unreported (Eskelinen et al. 1989). However, it has been argued, that major and minor accidents have different causation (e.g., Salminen et al. 1992). Therefore, differences between these groups are possible, since accident incidence-affecting factors may have a different effect on major and minor accidents. Recognised factors for the declining trend include the introduction of the insurance premium bonus system in 1997 (10% reduction in claims) and under-reporting minor injuries (Rautiainen 2002). Since farmers' employment accident insurance has covered all active self-employed farmers since 1982 (Mela 2002b), the trend examinations are considered reliable and representative. Nevertheless, several trends in society and agriculture, including safety promotion, have effects which would require further study.

The accident rates by year calculated in this study from the statistics of Mela are different from results in the literature based on surveys (Susitaival & Husman 1994; Kaila-Kangas et al. 2000, Laitinen 2000). Comparing the statistical trend and yearly rates to rates for all industries (Statistics Finland 2002a and 2002b; Karjalainen et al. 2000, Laitinen 2000), bearing in mind the under-reporting in statistics, stochastically fluctuating nature of accident incidence (Groeneweg 1992, Hocking & Thompson 1992) and comparability and reliability issues of sample studies, one can conclude that, for Finland, despite the decline, the level of accident risk is still relatively high in agriculture.

Tractor accidents

Ingress and egress associated with tractor cabins was chosen as a target of closer examination of causal factors with tractor accidents. The results presented in articles I and II demonstrate that access path usage is one of the most hazardous tasks related to the use of tractors. Gustafsson et al. (1991) and Hammer (1991) support this result and recommend that this assisting phase of work be an important target of safety intervention.

Myers (2001) has reported a similar share of tractor accidents in the United States as presented in this study. Virtanen et al. (2003) reported a share of 5.5% in a comprehensive Finnish national register linkage study. Shares between 7–9% are commonly reported (Napier et al. 1985; Hansson et al. 1989; Lee et al. 1996, Langley et al. 1997). However, a proportion as high as 28% has been noted (Pickett et al. 2001). In the latter case, the hospitalisation data of acute injuries underestimated the numbers of non-machinery injuries. Although direct comparisons between shares are not appropriate due to many differences in the research, a cautious conclusion regarding tractor accidents in Finland is that it is not likely that the state of tractor safety is worse here than elsewhere in industrialised countries. Non-fatal tractor accidents do not seem to be a major safety problem if valued only by the total frequency of occurrence, but in the use of the tractor there are work phases which are relatively dangerous and need attention, as discussed in Chapter 5.2.

Tractor accidents were not evenly distributed throughout the year; the months from May to August account for the majority of accidents. May seems to be an especially high-risk month, when the monthly working hours of males in plant production is the proximate for tractor work hours (I). Depending on the growing season in a country, similar results about high frequency months involving planting, cultivating and harvesting have been reported by Hansson et al. (1989), Lee et al. (1996) and Gerberich et al. (1998). The number of hours worked explains the high frequencies. However, Stallones et al. (1997) found that work-related injuries were associated with an increased workload. The highly intensive, short seeding as well as harvesting periods, especially in Finland and in other northern regions, may result in fatigue, risk-taking and stress contributing to errors, which is assumed to explain higher relative accident risk during these periods. Nevertheless, the working hours of males in plant production used as a denominator data is not an accurate measure for relational exposure to tractor use over all months. Therefore, for future studies exact data related to the amount of exposure in tractor work is needed for tenable conclusions about relative incidence of tractor accidents by months or operations.

Tractor accidents were not evenly distributed across the provinces of Finland, in relation to the number of registered tractors by province (I). Regional differences in either machinery- or tractor-related and all farm accident incidences have been reported also by Tupi and Vohlonen (1983), Lee et al. (1996), Gerberich et al. (1998) and Thelin (2002). In this thesis, more accidents in relation to the number of registered tractors were found in the eastern and central parts of Finland than in the southern and southwestern regions. The findings of Tupi and Vohlonen (1983) support this. Mixed operation, small-scale farming and its related relatively high machinery exposure are assumed to be among possible factors that could explain higher incident areas (Tupi & Vohlonen 1983, Thelin 2002). Regional differences in farming and related changes in exposure are assumed to reflect differences in hazard exposure. However, regional differences in claims are also possible.

About two-thirds of the tractor accidents occurred while mounting or dismounting the cab or when hitching or unhitching implements, each having the share of about one third of all tractor accidents. Other researchers (Gustafsson et al. 1991; Hammer 1991, Lee et al. 1996) have also found these two auxiliary tasks to be the most hazardous phases of work related to non-fatal accidents and near-accidents with tractors. Nevertheless, the shares are somewhat different from study to study. The share of access path accidents vary in the range of 20–50%, and accidents when hitching or unhitching implements take up 11–42% (Gustafsson et al. 1991; Hammer 1991, Lee et al. 1996). Variations stem from differences in the study populations, methods and point in time of the research. Although deviation of working-hours in different tractor work tasks is not available, it is obvious that the shares of work-hours spent in ingress or egress or in hitching or unhitching implements are low compared to the total working hours, most of which are spent driving the tractor. This indicates that these tasks are obvious targets for accident prevention, especially when the relatively high severity of accidents noted is taken into account.

Accident consequences reported here, that is severity, injured part of the body and injury types are similar to what is reported in the literature (Napier et al. 1985; Hansson et al. 1989; Lee at al. 1996, Langley et al. 1997). This implies that despite the differences in agricultural production and machinery between countries, agricultural engineering is similar enough in terms of ergonomics to produce similar outcomes.

Tractors used more frequently, although newer, were more often involved in accidents. The assumed pattern of use differs from tractor to tractor on a farm, resulting in differences in risks between tractors. This was not measured in this thesis. However, the general condition and safety of equipment was controlled with case studies. The condition and safety features of "accident tractors" proved to be better than those of all tractors in the data (II). The reason for the higher accident incidence proved to be related to the higher number of work hours with newer tractors. Insufficient or inadequate safety equipment contributed to an accident in 14% of the cases, however. As noted before, the accesses to cabs were in unacceptable condition in 40% of the cases, but the condition of accesses did not seem to contribute to the accident directly. Imperfection in three-point contact during the movements and the flexible lowest step were observed with motion analysis in the pilot study of movement practises on access paths as possible contributing factors to accidents (III). McGwin et al. (2000) reported significantly higher injury rates for farmers using farm equipment in fair or poor condition. Poorly functioning or braking tractors place farmers at accident risk. Machinery in poor condition may require more maintenance and repair than properly-functioning machinery, which adds to risks. It has been also suggested that poor-quality equipment may serve as an indicator of other factors increasing injury risk, for instance less interest in safety (McGwin et al. 2000).

The insufficient awareness of operators about safety issues was confirmed by Browning et al. (1998) and Thelin (2002). The varying and seasonal nature of farming and traditionally unsafe working methods (noted also, for instance, by Murphy 1981, 1992) add to the risks.

Management and safety

Measures taken to avoid known hazards seem to be more infrequent in agriculture than in other industries (II). This, as well as the exhaustion and delays in work, indicates shortcomings in safety management (IV). Farmers reporting high numbers of machinery and musculoskeletal disorders appear to have a higher accident rate (IV). If working capacity, whether mental or physical, is not equal to the tasks to be performed, the accident probability increases, as noted in earlier studies (Browning et al. 1998; Lewis, et al. 1998; MacCrawford et al. 1998, Zwerling et al. 1998). Elevated exhaustion and health disorders may explain the increased incidence of accidents. However, biases in self-reporting and accident claim behaviour connected to personal traits may affect this result.

Biases in self-reporting are possible also in the case of frequently delayed operations. Considering this, however, tasks not performed in a timely manner imply pressures which may result in haste and, on the other hand, to managerial shortcomings. This indicates the hypothesised connection between accident incidence and management quality according to the organisational accident theory.

Generalisation of the results

The results of this thesis are primarily applicable to tractor- and machinery-related work by males in agriculture in mechanised family farming. The conclusions are assumed to be partly applicable to farming in general in industrialised countries, and slightly applicable to self-employed people in general in micro-companies (companies with less than 10 workers).

6.3 Accident prevention

Safety management

According to the results of this study, in more than 90% of the accident cases better working methods and habits would have prevented the accident (I). The implications of deficiencies in planning and in developing working methods suggest that better management is a key issue in safety promotion. Better management and planning are needed during intensive spring farming operations when the need for appropriate resource allocation is critical.

To lower the pressures of business management and cut down high-risk non-productive tasks, there is a need to develop easy-to-use integrated production control and decision-making instruments for farmers to help in administration and planning. There should be more efficient safety-promotion programs to provide farmers with easy-to-use tools and other support for better overall management of the enterprise, which would work better than an aim to change behaviour on a task level through counselling. Better management tools should result in higher quality operations and reduce disturbances and other delays which may be risk factors for accidents (IV). Better business management should result in production that is more profitable and thereby make possible investments favourable to safety. Moreover, better mental and physical health could be achieved due to better control of farming and life, since uncontrollable and unpredictable problems in farming are experienced as stressful (Raine 1999).

Others (Murphy 1981; Park & Hartley 2002, Thelin 2002) have proposed decision-making, planning and systems design to be targets for farm accident prevention. Improving the marketing of agricultural products and increasing profitability are among suggested strategic interventions (Day 1999). Better organisational management can influence these areas also. The influential role of work organisation in relation to behaviour, errors, and accidents has been proven in industrial settings (Feyer et al. 1997).

Vocational education does not seem to have a significant effect on injury risk (IV). Murphy (1981), Reis and Elkind (1997), Lewis et al. (1998) and DeRoo and Rautiainen (2000) have presented similar findings on the limited success of education and safety training in promoting safety. However, improvement of farm-management and self-management skills through education would be beneficial. Therefore, improving vocational education is suggested. Additionally, education and counselling aimed at raising awareness of hazards appears to be necessary (I, II). Occupational safety is promoted also by measures, such as participation in the farmers' occupational health service and early rehabilitation, which promote a good capacity to work. Another suggested method for prevention is developing and promoting working methods for agriculture that diminish haste and the resultant errors (I).

Formal general management practises or safety management practises are not often applied although it seems to be beneficial in the current safety and quality policy situation of agriculture. This is suggested as a new, effective intervention strategy for agriculture that should decrease both general failures and stress in the management of a farm. Further research should focus on finding the proper substance, form, and technologies of beneficial and usable management tools. Furthermore, ways to promote the use of such tools should be studied.

Engineering solutions

The influence of ergonomics as a contributing factor to accidents was presented in article III. The subject of research was accidents on access paths. Examples of failures in design, which logically contribute to accident probability, were detected. It was shown that the designs of access routes, as well as procedures for hitching and unhitching implements, deserve attention. Furthermore, musculoskeletal disorders and the possession of many pieces of machinery were related to the elevated risk of an injury (IV). If farmers' health deteriorates, their work should be lightened and mechanised. Suitable designs for machinery, working methods, and tools – in short, better technology – should be developed, and promoted by extension services.

Therefore, developing engineering solutions and better ergonomics appears to be a way to promote safety in agriculture. The safety standard of the tractors (I, II, III) or machinery in general is not the highest possible in all areas, despite new harmonised regulations in the EU (Kivistö-Rahnasto 2000) and this deficiency suggests routes for accident prevention.

The literature review gave further implications of the need for better usability of engineering solutions in agriculture. The safety of knowledge-intensive production is dependent on high-quality utility of information processing and control of machinery. Therefore, research and development is needed in this area.

6.4 Implications for the future

The structure of agriculture will continue to change in the future. The average size of the farms and amount of work for remaining farmers is still increasing. This leads to increased exposure to hazards. There is beginning to be a shift from a commodity mindset to a more entrepreneurial mindset, with an increase in vertical integration and more specialty crops produced for niche markets (Krutz & Schueller 2000). One of the major challenges facing farmers is enterprise management that incorporates increased modern mechanisation (Weick 2001). The decreasing profitability in agriculture and the increasing farm size compel more efficient machine-dominated work. The need for planning operations and economy has grown and this has resulted in more time spent on management in Finland (Hirvonen 1997, Ristiluoma & Sipiläinen 2003).

This development has a potential for both benefits and threats to the safety and health of farmers. It has been realised that the increased automation afforded by cheap computing power also offers greater opportunities for the insidious accumulation of latent failures within the system and complex, hazardous technologies have become less transparent to the user (Reason 1995). In agriculture as well, automation and newer practises together with growing size and power of machinery have introduced new risks (Stoskopf & Venn 1985, Pickett et al 2001).

However, applications of information and communication technology (ICT) offer possibilities to process information needed in management. According to Thysen (2000), farmers will require ICT applications which can support their efforts to manage their farms according to the expectations of government administrators and agri-chains. Easy-to-use efficient management tools will ease the burden of management and create rational farm- or farm- group specific work organisations, which enhance safety. Tractors and machinery as well could benefit from the development, if the usability, safety and integration of machinery to the production processes are well-thought out and implemented.

Farming is already an information-rich occupation. There is a pressing need to develop and incorporate models and expert systems to interpret and integrate multi-source data into useful information (Stafford 2000). When developing these models and systems, one should focus on the social sustainability and the well-being of the farmer. High-quality usability and a low threshold for implementation are among the most important aims in machine and management tool design.

7 Conclusions

The results of this study are based on joining the results of the literature review, statistical analysis, and case studies in the context of the organisational accident theory. According to the literature review, agricultural production is multiform by nature and subject to a wide variety of hazards. Machinery, animals, or falls are often among the immediate, proximal accident factors. The deviations resulting from the unstable characteristics of production and its environment explain the emergence of several hazards. Operations involving increased variation in both tasks and circumstances as well higher numbers of disturbances have been generally noted to increase accident probability. Injuries in agriculture are often severe and affect enterprise profitability and functioning.

In this study, it was discovered that the level of accident risk is still relatively high in agriculture. The trend of the accident rate in total is in slight decline, but there are implications of less favourable developments. Therefore, statistics and trends should be evaluated in more detail, focusing on reasoned subcategories of indicators. Several trends in society and agriculture, including safety promotion, affect the development of the accident rate and require further study.

According to the study results, working with agricultural tractors includes high-risk tasks that should be attended to. These tasks are hitching and unhitching the implements and using the access path. The major causes of accidents that take place during these tasks include ergonomic defects and deficient conditions of the tractors. These factors are connected to one further important causal factor, unsafe work practises. Therefore, improving the usability of tractors would decrease the accident risk in two ways: directly due to decreased hazards, and indirectly by guiding the users to safer behaviour. However, in aggregate the number of non-fatal tractor accidents is not alarmingly high in Finland.

A purpose of this study was to introduce the management issues for research and discussion of agricultural safety and health research. The connection between accident incidence and management quality, according to the organisational accident theory, was studied. As a result, it is proposed that this line of study is worth continuing. According to this study, further measures of management quality should be sought and the ones employed in this study retested and incorporated into a wider, modern epidemiological study design of accident risks. For instance, productivity could be utilised as an additional measurement of management quality and denominator of injury incidence.

As a result of this study, a new approach that combines organisational accident theory and a public health approach for studying accidents of the self-employed in micro-companies was developed. The methodology applied proved to be useful for the intended purposes. However, the utilisation of the public health approach in full is very resource intensive and the methods are not fully established. Therefore, further contributions are needed to develop a practical research methodology. Especially, the different theoretical premises of accident causation should be acknowledged both in research and safety promotion.

According to this study, accident incidence for agriculture in Finland still is on such a high level that traditional preventive measures, i.e., engineering, education, and enforcement, will have the power to change things for the better. The usability of high-tech machinery and tools needs particular attention. However, in addition to this work, attention to accident prevention should also involve managerial chores in farming. Safety management offers a sustainable way to enhance the safety and health of farmers.

8 References

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9 Appendix

Appendix 1. Descriptions of variables related to management.

Variable name	Type of data	Variable description
Delays	Continuous (dichotomized)	Self-reported quality and success in management. The question was "How often are tasks delayed in relation to the planned timetable?" Respondents selected from a ten-point scale ranging from "all the time" (1) to "hardly ever" (10). For the analysis, the answers were dichotomized to: not marked (numbers 5–10), significant (numbers 1–4)
Number of machines	Continuous (categorized)	The number of machines measured hazard exposure. In the questionnaire, 36 groups of machinery were predetermined and the possession and quality of machines of each type was asked. The total number of machines on the farm was grouped: less than 15, 15–25, more than 25.
Musculoskeletal disorders or MSD	Categorical (dichotomized)	The incidence of musculoskeletal disorders (MSD) was asked in order to measure a physical dimension of health often problematic in agriculture. The question was: "Have you experienced ailments of muscles or joints in the back, shoulders or limbs during the past 12 months?" The choices were "not at all", "seldom", "often", and "I have consulted a physician or specialist because of ailments". The variable was dichotomized for analysis by grouping the first two choices and the latter two choices together.
Exhaustion	Categorical (dichotomized)	Self-reported exhaustion indicating coping with stress. Exhaustion measures the balance between work demands and capabilities, both mental and physical. The question was: "Have you experienced exhaustion during the past 12 months?" The choices were "not at all", "seldom", "often", and "I have consulted a physician or specialist because of exhaustion". The variable was dichotomized for analysis by grouping the first two choices and the latter two choices together.