Assessment of occupational safety determinants in Finnish agriculture and commercial fishing

Doctoral Dissertation

Kim O. Kaustell

Luke

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Academic dissertation

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Abstract

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Agriculture and commercial fishing are among the most hazardous occupations worldwide, also in Finland. Various efforts have been developed to prevent and mitigate the effects of occupational accidents and diseases. The process of risk management comprises two significant stages: 1) risk assessment, and 2) risk treatment. Occupational safety and health (OSH) risk assessment builds on the evolution of accident causation models and of knowledge on human behavior over several decades. Risk treatment has also evolved, ranging from limited targeted efforts to multi-faceted interventions.

The aims of this thesis were to identify factors that influence the incidence and severity of occupational accidents (risk assessment approach) and work system related factors that affect efficacy of occupational safety interventions (risk treatment approach). Information of the identified factors, called "occupational safety determinants" in this thesis, was composed into a list of occupational safety determinant clusters with respect to their contribution to occupational safety risk assessment and risk treatment.

Four original articles were used as case studies to derive occupational safety determinants. Two of the articles focused on the occupational safety of farmers while the two other articles dealt with that of commercial fishers. For both occupations, there was one article based on accident insurance claim records, and one article based on user (farmer/fisher) centered surveys.

The list of occupational safety determinant clusters was used to facilitate the assessment and discussion of occupational safety determinants. The list comprises the following nine titles: Physical environment, Organization and management, Individual, Task, Tools and technologies, External, Performance, Intervention mechanisms, and Intervention drivers and barriers.

Analysis of occupational accident insurance claim records with a limited set of variables yielded a narrow quantitative set of safety determinants that mainly described the immediate accident context. The result was expected, because the national and the European Statistics on Accidents at Work (ESAW) methods include sparse if any information on distal factors to the accident, such as the effect of work organization, management, or external factors of the accident etiology. The user centered surveys yielded a broader qualitative spectrum of occupational safety determinants, and provided also insight into additional, macro-ergonomic factors, such as the social and organizational context as well as contextual factors potentially influencing adoption of safety interventions.

User centered research methods along with research that is based on accident claim records can assist in designing more effective occupational safety interventions. These methods contribute to understanding the individuals' behavior in the context of work,

both from accident and hazard analysis as well as from the accident prevention view-point. Multi-faceted approaches are needed to provide comprehensive information that is essential for reducing the excessive burden of injury and illness in agriculture and commercial fishing.

Keywords: agriculture, fishing, occupational safety, risk management

Tiivistelmä

Maatalous ja kalastus ovat vaarallisimpia ammatteja myös suomalaisessa maataloudessa ja kaupallisessa kalastuksessa. Työtapaturmien ja sairauksien ennaltaehkäisemiseksi ja lieventämiseksi on kehitetty erilaisia toimenpiteitä. Riskienhallinnassa on kaksi vaihetta: 1) riskien tunnistaminen ja arviointi ja 2) riskien torjunta. Työturvallisuus- ja työterveys-riskien arviointi perustuu syy-seurausmalleihin, ihmisen käyttäytymiseen liittyviin malleihin sekä ammattitautien epidemiologiaan. Myös tapaturmien ja ammattitautien torjunta on kehittynyt rajallisista, kohdennetuista toimista kohti monitahoisia ja -vaikutteisia työterveys- ja -turvallisuusinterventioita.

Väitöskirjan tavoitteena oli tunnistaa työtapaturmien esiintyvyyteen ja vakavuuteen vaikuttavia tekijöitä (riskien tunnistaminen ja arviointi) ja työn kokonaisuuteen liittyviä tekijöitä, jotka vaikuttavat työturvallisuusinterventioiden tehokkuuteen (riskien torjunta). Tiedot tunnistetuista tekijöistä, joita tässä tutkimuksessa nimitetään työturvallisuuden determinanteiksi, luokiteltiin väitöskirjassa koostettuun listaan työturvallisuuden determinanttiklustereista.

Väitöstutkimuksen taustamateriaalina käytettiin kirjallisuuden ohella neljää aiemmin julkaistua tieteellistä artikkelia. Näistä kaksi liittyi viljelijöiden ja kaksi kaupallisten kalastajien työtapaturmiin ja työturvallisuuteen. Kummankin ammatin osalta toinen artikkeli perustui tapaturmavakuutustietoihin ja toinen viljelijöiden tai kalastajien haastatteluihin.

Työturvallisuuden determinanttiklusterien luetteloa käytettiin jäsentämään determinanttien muodostusta ja käsittelyä tässä työssä. Luettelo sisältää seuraavat yhdeksän nimikettä: fyysinen työympäristö, organisaatio ja hallinto, yksilö, tehtävä, työvälineet ja tekniikat, ulkoiset tekijät, suorituskyky tai -taso, interventioiden mekanismit ja interventioiden toteutumista edistävät ja haittaavat tekijät.

Työtapaturma-aineistojen käyttö determinanttien analysoinnissa tuotti rajallisen määrän erilaisia muuttujia, jotka kuvasivat lähinnä onnettomuuteen välittömästi liittyviä tekijöitä. Tulos oli odotettu, sillä tilastojen aineistokeruuseen liittyvät, vakioidut menetelmät sisältävät vain vähän tietoa onnettomuuden välillisistä determinanteista, kuten työn organisoinnista ja johtamisesta tai epäsuorista, ulkoisista syytekijöistä. Käyttäjäkeskeiset tutkimukset tuottivat laajemman kirjon työturvallisuuteen vaikuttavista tekijöistä. Ne antoivat myös viitteitä makroergonomisista tekijöistä, kuten sosiaalisista ja organisatorisista tekijöistä, sekä työn ja työympäristön kokonaisuuteen liittyvistä tekijöistä, jotka voivat vaikuttaa turvallisuustoimenpiteiden toteuttamiseen.

Käyttäjäkeskeiset tutkimusmenetelmät sekä tapaturmatilastoihin perustuva tutkimus voivat auttaa tehokkaampien työturvallisuustoimenpiteiden suunnittelussa. Nämä menetelmät auttavat ymmärtämään yksilöiden käyttäytymistä työympäristön kokonaisuudessa sekä tapaturmien ja vaaratekijöiden analysoinnin että tapaturmien torjunnan näkökulmasta. Monipuoliset ja -tieteiset lähestymistavat ovat välttämättömiä kattavan

taustatiedon tuottamiseksi, jotta maatalouden ja kaupallisen kalastuksen tapaturmia saadaan torjuttua nykyistä tehokkaammin.

Asiasanat: kalastus, maatalous, riskienhallinta, työturvallisuus

Forewords

The idea for this thesis study developed during repeating moments and discussions around why agriculture and fishing are year after year among the most hazardous industries. Many research projects had passed, incrementally contributing to knowledge of unsafe work and suggestions on how to mitigate occupational safety problems. I found myself revisiting thoughts of the interplay between the human, the work context, and efforts to prevent accidents. Consequently, an overwhelming pool of occupational safety related factors started to surround me. This thesis is an effort to get a grasp on these factors – called occupational safety determinants – in the hope to promote comprehensive occupational safety approaches concerning both accident analysis and prevention.

I extend my warm thanks to Professor Laura Alakukku and Docent Hanna-Riitta Kymäläinen for their professional and determined guidance throughout this thesis project. I also want to acknowledge Professor Risto Rautiainen for his outstandingly professional supervision as well as the enlightening discussions and common research projects along the years. I am also sincerely grateful to the pre-examiners, Professor Stephan Van den Broucke and Professor Trond Kongsvik, for their insightful and constructive comments on the manuscript.

It has been a pleasure to work with the numerous co-authors and colleagues whose enthusiasm and devotion for occupational safety has inspired me. I wish to thank you all, with special thanks going to Docent Janne Karttunen and Dr. Trine Thorvaldsen who took the time to comment on my thoughts and ideas, as well as to encourage me during this journey. I am also grateful to the Natural Resources Institute Finland (Luke) and my office colleagues Dr. Lauri Sikanen and Docent Juha Suutarinen for their kind support as well as Professor emeritus Jukka Ahokas for his guidance as a member of the thesis committee.

The Farmers' Social Insurance Institution Mela has kindly provided accident insurance data, expertise, and funding for numerous of my research projects along the years, for which I want to express my warmest compliments. I feel this support has been crucial for maintaining occupational health and safety of farmers, fishers, and reindeer herders on the research agenda in Finland.

Finally, I thank my family for bearing with me during even my most absent-minded periods, and giving me all the time, space and warm support needed for this thesis project.

List of original publications

This doctoral thesis is based on the following original articles. The Roman numerals are used throughout the text when referring to these articles.

I   Kaustell, K.O., Mattila, T.E.A. & Rautiainen, R.H. (2007). Safety Performance of Animal Confinement Floors: Slip, Trip, and Fall Injuries in Finland. Journal of Agricultural Safety and Health 13(4): 395-–406.

II   Kaustell, K.O., Mattila, T.E.A. & Rautiainen, R.H. (2011). Barriers and enabling factors for safety improvements on farms in Finland. Journal of Agricultural Safety and Health 17(4): 327-–342.

III   Kaustell, K.O., Mattila, T.E.A., Hurme, T., Salmi, P.S. & Rautiainen, R.H. (2017). Predictors for occupational injuries and diseases among commercial fishers in Finland 1996-–2015. International Maritime Health 68(4): 196-–202.

IV   Thorvaldsen, T., Kaustell, K.O., Mattila, T.E.A., Høvdanum, A. á., Christiansen, J.M., Hovmand, S., Snorrason, H., Tomasson, K. & Holmen, I.M. (2018). What works? Results of a Nordic survey on fishers' perceptions of safety measures. Marine Policy 95: 95-–101.

Contributions

The following table presents the contributions of the authors to the original articles of the dissertation:

Task	Article I	Article II	Article III	Article IV
Initial idea	KK	KK	KK	TT, KK, JC, AáH, KT
Logic of reasoning	KK	KK, TM	KK, RR	TT, KK
Acquisition of funding	KK	KK	KK	TT, KK, JC, AáH, KT
Collection of data	KK	KK, TM	KK	KK, TT, TM, AáH, JC, SRH, HS, KT, IH
Analysis of data	KK, TM	KK, TM	KK, TH	KK, IH
Original manuscript	KK, TM, RR	KK, TM, RR	KK, TM, TH, PS, RR	TT, KK
Corresponding author	KK	KK	KK	TT
Revision of the manuscript	KK	KK	KK	TT, KK, TM, AáH, JC, SRH, HS, KT, IH

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RR	Risto Rautiainen, University of Nebraska Medical Center, USA
TH	Timo Hurme, Natural Resources Institute Finland (Luke)
PS	Pekka Salmi, Natural Resources Institute Finland (Luke)
TT	Trine Thorvaldsen, SINTEF Ocean AS, NO
JC	Jørgen Møller Christiansen, University of Southern Denmark
AáH	Annbjørg á Høvdanum, the Faroese University
KT	Kristinn Tómassen, Administration for Occupational Health and Safety, IS
SRH	Sarah Rettig Hovmand, University of Southern Denmark
HS	Hilmar Snorrason, Maritime Safety and Survival Training Centre, IS
IH	Ingunn Marie Holmen, Norwegian University of Science and Technology

In article I, M.Sc. Tiina Mattila contributed to data analysis by performing phrase analysis on the injury claims records. The corresponding parts of the manuscript were written by her while Prof. Risto Rautiainen reviewed the text and provided guidance on methodological issues.

In Article II, the Cultural Probes method adaptation, study design, data collection, analyzes, and reporting were conducted by lead author Kim Kaustell in cooperation with Tiina Mattila. She also contributed to writing the original manuscript. Prof. Rautiainen reviewed the text and provided information on international aspects.

Article III involved assessment or predictors (risk and protective factors) for occupational accident and disease claims using longitudinal insurance data for all insured self-employed fishers in Finland over a period of two decades. Prof. Rautiainen assisted in this task, while M.Sc. Timo Hurme assisted in performing the multivariable logistic regression analysis. Along with the mentioned contributors, Dr. Pekka Salmi and Tiina Mattila contributed to writing parts of the discussion and conclusions of the manuscript.

Article IV is based on data collected in a joint Nordic research project. The research group, Dr. Trine Thorvaldsen (NO), M.Sc. Kim Kaustell (FIN), Dr. Jørgen Møller Christiansen (DK), M.Sc. Annbjørg á Høvdanum (FO), and Dr. Kristinn Tómassen (IS), agreed on publishing a joint journal article, and the task was delegated to Dr. Thorvaldsen and Kim Kaustell. The research group's common contribution thus also shows in acquisition of the original funding, collection of the original data, and revision of the manuscript. Dr. Thorvaldsen also acquired additional funding for compiling and publishing the article. Dr. Ingunn Marie Holmen assisted in organizing the common data for analysis. Tiina Mattila contributed to revising the final manuscript using the original project report as a reference.

Abbreviations and definitions

Accident at work	"Discrete occurrence in the course of work which leads to physical or mental harm" (Eurostat European Commission 2013). Both "injury at work" and "accident at work" are frequently used to describe the same event in research literary, alternatively including or excluding material harm.
Activity	Describes 1) economic activity (e.g. agriculture or fishing), 2) specific physical activity of the accident victim, and 3) general actions of a person. The two first uses abide by the definitions of the European Statistics on Accidents at Work [ESAW] (Eurostat European Commission 2013).
Causality	Accident-oriented concept of the relation between a cause and its effect or between regularly correlated events or phenomena.
Close call / near miss	An unplanned event which did not result in injury, illness, or damage – but had the potential to do so.
Determinant of occupational safety	Factor that influences the incidence and outcome of injuries and/or affects adoption and implementation of safety interventions. For a wider contemplation, see Subchapter 2.8.
Determinant cluster	A consolidated group of similar occupational safety determinants, as used by Cornelissen et al. (2017).
Epidemiology (of accidents)	Describes "…the distribution and determinants of occupational injuries and to make and test inferences about their prevention." (Hagberg et al. 1997)
ESAW	European Statistics on Accidents at Work
Etiology (of accidents)	Accident prevention oriented conceptual model of factors, circumstances and their relations that add to the probability of the accident.
Harm	Negative physical, socio-physical, economical or environmental outcome of a realized occupational risk.
Hazard	Source with a potential to cause an adverse effect on the physical, mental, or cognitive condition of a person (International Organization for Standardization [ISO] 2018a).

Incidence rate	Calculated ratio of compensated occupational accident claims and number of insured individuals in the same population.
Injury (occupational injury)	Used as a synonym for accident (at work).
Intervention (occupational safety and health intervention)	An attempt to change the course of work and working methods, in order to improve safety. Safety interventions include all such intentional acts regardless of whether they are initiated or manifest themselves outside ("external interventions") or inside the workplace.
Mela	Finnish Farmers' Social Insurance Institution (Maatalousyrittäjien eläkelaitos).
Occupational injury claim	A registered and compensated injury record on a social insurance company's database.
OH services, OH center	Occupational health (OH) services are offered by private or public occupational health centers.
OSH	Occupational safety and health. For a wider contemplation, see Subchapter 2.1.
PA, Performance approach	A planning concept of buildings, where properties of buildings are defined with respect to the needs of the building user and use processes (Spekkink 2005).
Risk	The combination of the likelihood of the occurrence of harm and the severity of that harm (ISO 2018b).
Risk management	"Coordinated activities to direct and control and organization with regard to risk" (ISO 2018b). For a wider contemplation, see Subchapter 2.2.
Safety management	Safety management is an integral part of risk management that focuses specifically on mitigating health and safety risks (Baumann et al. 2012, Leppälä 2016). It comprises two main stages of risk management: risk assessment and risk treatment.
Safety measure	An activity with the aim to promote occupational safety and health.
Safety outcomes	"Negative events in the form of incidents, accidents, or injuries" (Cornelissen et al. 2017).
STF	Slip, trip, and fall

| Work system | Elements and interrelations of the socio-technical system related to work. For a wider contemplation, see Subchapter 2.5. |

Contents

1. Introduction

In this chapter, the significance of the domain of this thesis research, occupational safety, is justified. Secondly, relevant approaches to occupational safety research and risk management are discussed. At the end of the chapter, the need for gaining a better understanding of the factors that determine occupational safety is presented.

Occupational accidents and diseases affect workers and their families, communities, businesses involved, and societies worldwide. The International Labour Organization has estimated that globally about 6000 people lose their lives each day due to these incidents. There are annually close to 340 million occupational accidents and 160 million people are affected by occupational diseases each year (International Labour Organization 2019).

While statistics provide an incomplete description of the occupational accident and disease burden (Merisalu et al. 2019), it is safe to estimate that agriculture and commercial fishing are among the most hazardous economic activities worldwide. In the European Union, agricultural, forestry and fishing activities ranked fourth among all economic activities with a 13.2% share of all fatal accidents at work in year 2015. Fishing and aquaculture had the highest and agriculture the third highest increase in the incidence rate of non-fatal accidents at work among all economic activities during 2010–2015, while most of the other activities showed decreasing incident rates (Eurostat 2019).

Finnish agriculture and commercial fishing are based on self-employing entrepreneurship with a varying amount of family workforce involved (Salmi 2005, Official Statistics Finland [OSF] 2019a). In 2016, 118000 persons worked in agricultural and horticultural enterprises, including 32,620 temporary workers, of whom 48% were foreign labor (OSF 2019b). In fishing, 4126 persons were registered as commercial fishers (OSF 2019c, OSF 2019d).

The incidence rate, calculated as the ratio of compensated occupational accident claims and of the number of insured individuals in the respective economic activities, has decreased over twenty years until 2010, followed by an upward trend. The average accident rate, calculated as the number of accidents per 100 insured farmers or farmer family members working on the farms, has varied between 5.6 and 8.2 during the years 1996–2019. The corresponding rates for fishers are 5.6 and 8.3 (Mela 2019a). During the period 2010–2018, compensation was made for 40395 occupational accidents to farmers and their co-working family members, fishers, and reindeer herders.

Occupational accidents resulted in a total loss of 1704 working years (365 days/year) and the sum of compensation during this period amounted to €244.1 million. The main causes in the insurance claim data records for occupational accidents and diseases (combined data) were structures and physical environment (34%), vehicles, implements, appliances, tools (28%), and animals (23%). Other causes comprise working movements and postures (8%), materials, biological, chemical and physical exposures (3%), and other, or not identified causes (3%) (Mela 2019a). Accidents account for 94%

of the insurance claims records. The order of relative frequencies of occupational acci-dent and disease causes has remained the same for the past two decades.

Both agriculture and commercial fishing have experienced structural changes espe-cially concerning the number of people employed (OSF 2019b, 2019c, 2019d) and changes in the economic and legislative environment due to e.g. the EU regulation and strengthened international competition over the past two decades. All these develop-ments add to the mental strain of farmers and fishers, exposing them to increased risk of occupational accidents and diseases (Lunner Kolstrup et al. 2013, Christiansen and Hovmand 2017). On the other hand, the EU and the European Agency for Safety and Health at Work (EU-OSHA) are striving to provide "a common minimum level of protec-tion from work related risks" to all workers in the EU member states. This legislative direction has translated to actual OSH management in varying degrees, considering the differences between countries and industries (Walters et al. 2013).

The ultimate goal of safety management is to mitigate and prevent occupational ac-cidents and diseases. Standardized approaches to risk management, such as the Interna-tional Organization for Standardization ISO31000 guidelines (ISO 2018b) and ISO45100 that are concerned with occupational safety management systems (ISO 2018a), have been developed to assist organizations in providing safer workplaces by implementing and auditing systematic occupational safety and health (OSH) measures. However, the capability of small organizations to invest in OSH activities or to assess and control risks is limited (Masi and Cagno 2015). Farmers prefer relevant and easily applicable man-agement systems. Specific management tools for agriculture and fisheries focusing on various aspects of OSH have been developed in many countries (Leppälä et al. 2015, Leppälä 2016, Christiansen and Hovmand 2017).

Several OSH and social insurance programs assist self-employed farmers and fishers in their systematic occupational safety management in Finland. Private or public occupa-tional health centers provide occupational health (OH) services which include health screenings, workplace safety assessments and consultation. The Finnish Farmers' Social Insurance Institution (Mela) administers statutory accident insurance and work-related pension insurance schemes for farmers and fishermen. Mela also coordinates OH ser-vices, administers farmers' holiday substitute services, produces OSH-related infor-mation and training courses, and finances small OSH research projects (Mela 2019b). Mela collects and delivers Finnish accident at work data of farmers and fishers to the Eurostat for statistical purposes. Additionally, a number of other public and private insti-tutions involving research and development, the occupational health system, extension and consultation services, vocational training, and trade organizations, are active in OSH-related matters.

Occupational accident research has used various approaches to assess the causes and causal relationships to establish the etiology of these accidents and to support safe-ty risk mitigation. At the same time, numerous occupational safety intervention research studies have evaluated the efficacy of interventions using randomized control trials and less rigorous research methods (DeRoo and Rautiainen 2000, Rautiainen et al. 2009) but

also by e.g. studying the potential of utilizing knowledge of human behavior and socio-ecologic models to maximize the impact of safety and health interventions (Lee et al. 2017). Socio-ecologic/socio-technical models are presented in Subchapter 2.5, and various models related to human behavior models are discussed in Subchapter 2.6.

The human oriented approach has evidently gained popularity, both in assessing the etiology of occupational accidents and the contributing effect of other contextual factors as well as in formulating effective ways to increase the impact of OSH interventions. Humans stand in the center of the work system, interacting with the context (Smith and Sainfort 1989) and occasionally becoming victims of accidents. At the same time, they are crucial actors promoting safety climate and safety considerations and actions on all organization levels.

The risk management process outlined in the ISO31000 (2018b) guidelines, as any informed development process, relies heavily on valid, representative and reliable data and the corresponding processing of these data. Promotion of occupational safety – be it a part of a formal, documented and systematic risk management process, or merely small, incremental safety improvements made in one's own work context – needs a multitude of data and knowledge to succeed. Information is needed to adapt the risk management process and measures to the respective context, to assess the risks and define the target of the initiative, to ensure effective and proper risk treatment, and to draw valid conclusions for continued occupational safety promotion.

Based on the above considerations, the following questions arise:

- What are the essential factors of the work system, including the socio-organizational context and external environment that ultimately determine the status quo of occupational safety in agriculture and commercial fishery?
- What do we need to know about these factors in order to enable effective safety risk management?
- How can we assess these factors?

This thesis research aims at answering these questions, with the intention of increasing the understanding of the underlying factors behind occupational accidents as well as contextual factors affecting accident prevention.

2.   Occupational safety related models and concepts

A framework of concepts and operational aspects is useful for discussing safety and safety promotion (Maurice et al. 1998). This chapter comprises a contemplation of what occupational safety means and how it relates to occupational health along with a short review of occupational safety related models and concepts, such as accident causation, risk assessment, and risk treatment. The review in this chapter intends to assemble a framework of concepts around the theme of occupational safety risk management without further evaluation of the reviewed, established models. A more in-depth presentation and discussion of various OSH-related concepts is outside the scope of this work. This chapter also serves the purposes of grounding the reasoning and methodological considerations of this thesis. With this framework of concepts, the central concept of occupational safety determinants is introduced.

2.1. Concept of occupational safety and health

One of the most comprehensive definitions of occupational safety and health (OSH) has been made by the International Labour Organization in "Fundamental principles of Occupational Safety and Health":

"Occupational safety and health (OSH) is generally defined as the science of the anticipation, recognition, evaluation and control of hazards arising in or from the workplace that could impair the health and well-being of workers, taking into account the possible impact on the surrounding communities and the general environment." (Alli 2008)

Common agreement exists that OSH focuses on occupation or work-related factors that affect both physical and mental safety, health and well-being (Alli 2008). It has been recognized that OSH performance correlates to other organizational performance (Lamm et al. 2007, Fernández-Muñiz et al. 2009, Cornelissen et al. 2017).

OSH has been widely defined, discussed, modeled, and researched from various viewpoints: governance from outside the organization in question, execution and activities of OSH management, risk treatment and management as well as outcomes. All these approaches complement the risk management process involving risk assessment and risk treatment.

Even the meaning of safety and health as well as their relation has been widely discussed. Maurice et al. (1998) suggest that safety is two-dimensional: 1) an objective state that can be operationalized by measuring objective parameters describing the environment (e.g. risk assessment) and the individual or individuals (e.g. safety related behavior), and 2) a subjective feeling (collective or individual, Maurice et al. 1998). Safety has also been characterized as being the complementary factor to risks in the human mind (Breivik 1999).

The definition of health, according to the constitution of the World Health Organization (World Health Organization 2006), encompasses "complete physical, mental and social well-being, not merely the absence of disease or infirmity". A multitude of medical, psychological, and sociological methods exist to diagnose or assess factors causing lowered well-being of a human or group of humans.

It has been suggested that "safety" relates to injuries and injury risks whereas "health" is more related to diseases (Cunningham 2016). Maurice et al. (1998), however, argue that safety is a prerequisite for maintaining and promoting health and the well-being of a population (Figure 1). The logic and chains of effect are in fact more complex than depicted in Figure 1 due to interactions between e.g. the environment, behavior and health status: A lowered physical performance of a worker may change her or his behavior and also necessitate changes in the physical environment. These changes may again have new implications on both safety, health, and well-being.
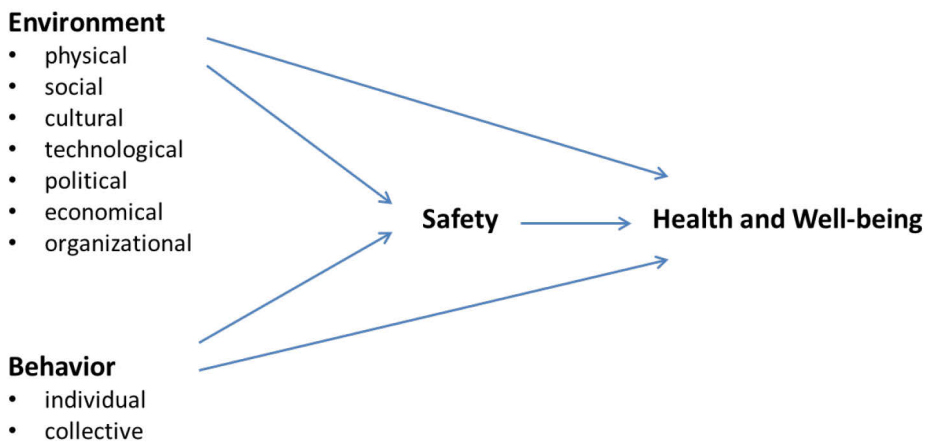
Figure 1. Links between safety and health (Maurice et al. 1998).

Occupational safety and health are often discussed and treated in combination with each other. This is probably due to their partially overlapping, typically complex etiology (Figure 1) featuring also reciprocal effects between safety and health. Both can lead to periods of inability to work, and mitigation of OSH hazards requires multifaceted cooperation (Mykletun 2000, Lamm et al. 2007, Sethi 2010, Pillay 2015, Chang et al. 2016, Lee et al. 2017). Institutional functions, such as OSH services and management as well as social insurance and record keeping (i.e. compilation of accident and health at work statistics) often combine safety and health in their communication and activities.

2.2. Risk management process

The ISO standard 31000:2018 (ISO 2108b) describes the general principles, framework and processes (Figure 2) that support systematic risk management in organizations, regardless of industry or its context.
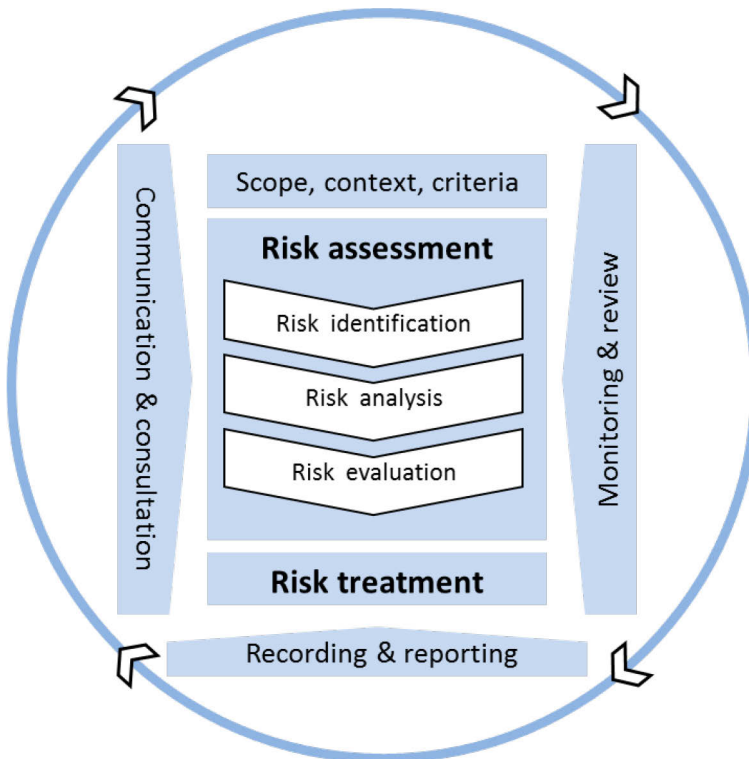
Figure 2. Stages of the risk management process (ISO 2018b).

The risk management process cycle comprises four stages: 1) establishing the scope, context, and criteria for risk management, 2) risk assessment, 3) risk treatment, and 4) continuous monitoring and review. On top of these, there are two supportive process stages: communication and consultation with both internal and external stakeholders and recording and reporting the risk management process and its outcomes.

A review on the internal and external context of the organization is necessary to obtain a thorough view on factors that make the organization being what it is and on how it operates. External context factors include e.g. the socio-cultural, legislative, financial, technical, and environmental factors. The internal context factors comprise, among others, the vision, mission and values of the organization, the organization's culture and adopted models of operation, resources and knowledge.

Risk assessment encompasses identification, analysis and evaluation of risks, using recorded and reported data as source information. The purpose of risk identification is to detect and describe existing and prospective risks that could prevent the organization to reach its goals. The identified risks are analyzed for risk factors and their relationships, relevant background variables, likelihood and consequences as well as risk control mechanisms and their efficacy. Finally, to facilitate choice of appropriate risk treatment measures, the identified risks are evaluated based on the risk analysis and with regard to the established contextual factors.

After the consideration of appropriate approaches to mitigate selected risks, a risk treatment plan is prepared and executed. The risk treatment also comprises a follow-up on the effectiveness of the treatment, i.e. evaluation of the remaining risk after the treatment. This follow-up combined with subsequent regular reviews constitute the monitoring and review stage of the entire risk management process.

All stages of risk management should be adapted to the needs and objectives of the organization (ISO 2018b), i.e. the organizational, operational, environmental, and economic context of the target organization and the work within the organization. This goes for the integration of OSH management into organizational processes as well as for methods, procedures, and data collection during safety risk assessment and treatment. In a literature study, Leppälä et al. (2015) found numerous risk management tools adapted and applied in farm environments to address asset, production, health and safety, economic, and environmental risks. Risk management tools related to fisheries were discussed by Sethi (2010), McGuinness and Utne (2014), and Thorvaldsen (2015).

Safety management is an integral part of risk management that focuses specifically on mitigating safety and health risks (Baumann et al. 2012, Leppälä 2016). Occupational safety research studies the incidence, characteristics, causes and prevention of workplace accidents (Linn & Amendola 1998). These topics correspond well to the two core stages of risk management process as described in ISO 31000:2018 (ISO 2108b): risk assessment and risk treatment.

2.3. Accident causation

The causality of accidents is complex (Rasmussen 1990, Suraji et al. 2001, Hollnagel 2016). Assessment of accident causes (i.e. accident analysis) is primarily motivated by accident prevention (Rasmussen 1990, Toft et al. 2012). To understand the underlying "accident factors", their mutual relations and the effect of these to the accident and accident prevention, a multitude of accident causation models has been developed.

Accident models serve six purposes (Hovden et al. 2010):

- Creating a common understanding of accident phenomena through a shared simplified representation of real-life accidents
- Helping structure and communicate risk problems
- Giving a basis for inter-subjectivity, thus preventing personal biases regarding accident causation and providing an opening for a wider range of preventive measures
- Guiding investigations regarding data collection and accident analyses
- Helping analyze interrelations between factors and conditions
- Highlighting various aspects of processes, conditions and causes in different accident models.

Different models focus on different aspects and are associated with different rec-ommendations for improvement (Svenson 1999). A commonly accepted model of acci-dent causation does not exist (Toft et al. 2012, Grant et al. 2018).

Accident models and etiology paradigms have evolved from simple, sequential cau-sality focusing on mechanical failures or accident proneness of the worker to current, systemic models involving interrelated socio-technical effects, human-machine rela-tions, variation, and uncertainty (Attwood et al. 2006, Katsakiori et al. 2009, Håvold 2010, Khanzode et al. 2012, Toft et al. 2012, Zohar 2014, Pillay 2015, Hollnagel 2016, Swuste et al. 2016). Simple linear models, like the Domino Model (Heinrich 1931), and the quest to pinpoint one single root cause to an accident were replaced by the concept of multi-causality (Katsakiori et al. 2009), examples being e.g. Rasmussen (1982) and Reason (1990).

Reason's (1990) the Swiss Cheese Model and its adaptations represent a complex and systemic model of accident causality (Toft et al. 2012). It takes an epidemiologic approach to accidents where the system has always latent failures ("resident patho-gens") that, in combination with active (immediately effecting) failures, can lead to loss-es. The latent failures exist on two "planes" or layers of the system: that of organiza-tion/management systems and that of task/environment/conditions. "Fallible decisions" in the top and line management as well as their implementation in the organization (= organizational features, conditions, Reason et al. 2006) promote emergence of latent failures (Reason 1990). The active failures, i.e. the behavior and actions of the person in frontline preceding the accident, are viewed only as the final step that reveals a set of latent failures (Katsakiori et al. 2009, Underwood 2013). For accidents to happen, active human failures are not necessarily required: accidents can occur merely based on a combination of latent failures (Underwood 2013).

Based on his model, Reason also suggested that accident research and prevention should focus – and would be most efficient – on all system levels to prevent emergence of latent errors (Wagenaar et al. 1990, Wagenaar and Reason 1990, Reason 2000). The latent errors are depicted as holes in the safety barriers of the respective levels in the model (Figure 3).
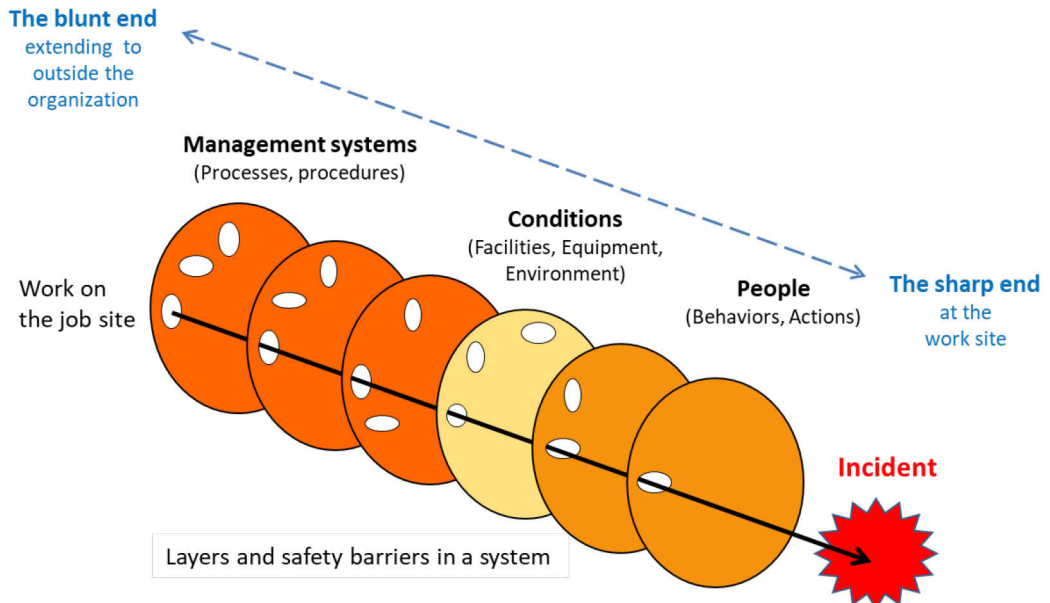
Figure 3. The layers and safety barriers in a system (adapted from Reason 1990 and Fennell 2017).

The metaphor of "sharp end" and "blunt end" represents "organizational distance" regarding the accident, but also reflects the difference between proximal and distal factors, which in an unfavorable constellation (rotational phases of the safety barriers, "filter discs" in Figure 3) may lead to an accident (Hollnagel 2016). The blunt end factors include e.g. ethical norms, morals, rules, regulations, and laws that modify the behavior of and choices available for organizations and individuals (Hollnagel 2008). The sharp end comprises the individuals at work and their immediate context.

Reason's model has been criticized, mainly due to it lacking explanation on the nature and causality for emergence of the latent failures (Luxhoj and Kauffeld 2003) and on the static nature of the layers (i.e. the context) and thus, the whole system (Dekker 2002, Qureshi 2008). The Swiss Cheese Model, along with other contemporary or earlier models, does not account for natural variation in the way organizations and individuals work (Toft et al. 2012).

The Functional Resonance Analysis Method or FRAM (Hollnagel 2012) is an example of complex and systems thinking involving accident causation models and prevention approaches. It builds on the following basic principles (Hollnagel et al. 2014):

1. Good or bad consequences can arise even if background factors stay the same. "Things that go right and things that go wrong happen in much the same way" (principle of equivalence of successes and failures)

2. Conditions vary, and people adjust to match the conditions (principle of approximate adjustments or performance variability)
3. Specific causes to consequences cannot always be identified (principle of emergence)
4. The "normal" or "safe" variations in parts of the system may coincide so that the resultant variation produces exceptional consequences (principle of resonance).

The FRAM and the related Safety-II approach suggested by Hollnagel et al. (2015) represent a paradigm shift in causality assessment. Instead of considering single causes and their relationships in a sequential order, focus should be on functions of the system (i.e. acts and activities that are needed to produce a result), their relationships, their variability under different conditions, and their mutual resonance. According to the principle of approximate adjustments, systems can "drift" to failure (Toft et al. 2012) without evident or retraceable causes (Figure 4).
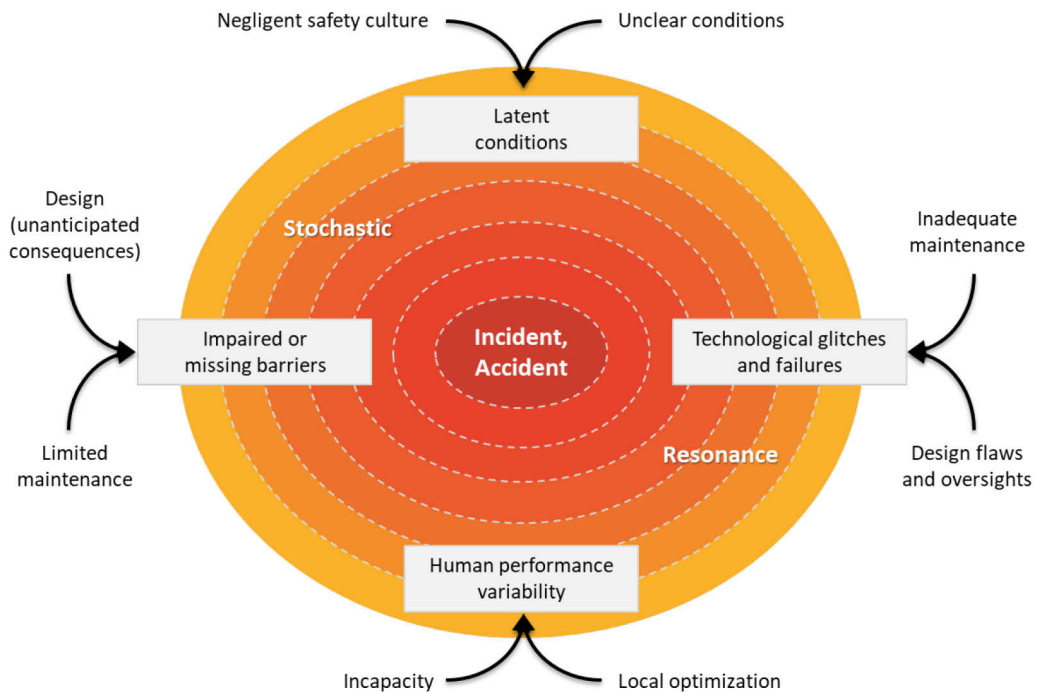
Figure 4. Functional Resonance as a System Accident Model (Hollnagel 2004).

The systems approach and models facilitate multi-disciplinary cooperation, which is necessary for understanding all different factors and effects involved in accidents (Carayon 2006, Underwood and Waterson 2013, Robertson et al. 2015, National Academies of Sciences, Engineering, and Medicine 2018). Regardless of the accident causation model applied, a key element of any meaningful accident assessment, prediction

and prevention effort is to know how the real system (work system, production process, organization, the humans involved etc.) works and of which parts and interactions it is comprised.

2.4. Occupational accident data sources

Occupational accident statistics are a commonly used source used for assessing causality and the context of the accident as well as characteristics of the accident, the victim, and the organization. Statistical sources of occupational accident data are widely used to describe accidents at work in order to assess risk factors and personnel groups at risk. These assessments are key to determining the most significant topics and target groups for accident prevention. Accident data are also used to assess the efficacy of interventions in e.g. randomized controlled trial settings (Rautiainen et al. 2009).

The ESAW methodology for documenting accidents at work provides a list of variables associated with accidents and serves as a common data content description of occupational accident records (Eurostat European Commission 2013). The basic information needed to describe an accident is presented in Table 1. The list of variables comprises two groups: one describing the main characteristics of the accident, the victim and the employer, and the other group providing information on accident causality and circumstances.

Table 1. Basic accident information in the ESAW methodology (Eurostat European Commission 2013).

Characteristics of accident, victim and employer	
Enterprise	Economic activity Size of enterprise Geographic location, date and time
Worker	Occupation Age and sex Nationality Employment status
Victim	Type of injury Body part injured Days lost

Variables on causes and circumstances	
Workplace	Working process Workstation
Working conditions	Working environment
Sequence of events	Specific physical activity and associated material agent Deviation and associated material agent Contact - mode of injury and associated material agent

Immediate accident outcomes (injuries, fatalities) as well as e.g. details describing the worker and victim comprise a relatively unambiguous (general) and industry independent set of descriptive factors. The outcome variables of recorded injuries, i.e. the consequences (type of injury, injured body part, severity) of the accidents serve as discriminators in assessing risk level and prioritizing preventive actions.

The EU member countries report occupational accidents according to the data content description depicted in detail in the ESAW Methodology Summary (Eurostat European Commission 2013). All occupational fatalities and accidents resulting in more than three calendar days of absence from work are recorded in the EU's statistical office (Eurostat). The reporting of occupational accidents in the member countries is mainly based on two incentives: insurance claims by the accident victim or the legal obligation of the employer (Eurostat European Commission 2013).

In Finland, Mela handles the statutory pension and occupational accident insurance of farmers and fishers and their family members, if they participate in farm or fishery work. For the employed work force in these occupations, the employer is obliged to insure the employees for occupational accidents and to report serious accidents to the OSH authority and police (Finlex 2006). The insurance company must also be informed. The Finnish Workers' Compensation Center (Tapaturmavakuutuskeskus, TVK) is responsible for collecting and compiling data on occupational accidents of employees from insurance companies. Both Mela and TVK provide anonymized accident data for research purposes.

While Eurostat only records accidents leading to four or more days of inability to work, Mela collects information also of accidents with less drastic outcomes. Mela also records more detailed information of the accidents containing e.g. subdivisions of the "Material agent" and "Working process" variables. The additional information is specific to Mela's insurance customer occupations (Mela, personal communication November 12, 2019).

Other documentation of accidents, which could be used as sources for detailed analysis of OSH determinants, includes investigations concerning legal liability for accidents, fatality investigations, and official accident investigation reports. In Finland, the first two are not made publicly available, but work accident and fatality investigation results are sometimes published by the Finnish Workers' Compensation Center (Workers' Compensation Center 2019) and by the Finnish Safety Investigation Authority. The Safety Investigation Authority assesses mostly major accidents and has published reports related to fishing vessels and serious accidents, including agricultural cases (Safety Investigation Authority 2019).

2.5. Work system and work context

The work system model was originally proposed by Smith and Sainfort (1989) to enable the analysis of stress factors that affect a worker and to facilitate the balancing of production and stress in work design. The person/worker is placed in the center of a web of

interactions between the identified work system elements: the organization, tools in use, tasks and the operating environment (Figure 5). The importance of the individual is based on its intermediating and moderating role in accident causation and intervention related models and research, as described by e.g. Hackman (2003) and Carayon (2006). The individual constitutes a meso level in the analysis of the work system. From that level, it is possible to assess the effects of the macro level that comprises the physical, mental and social context that affect the individual's behavior. Correspondingly, it is necessary also to study micro level concepts, such as physical or cognitive traits of the individual, to understand the individual's reactions and behavior.
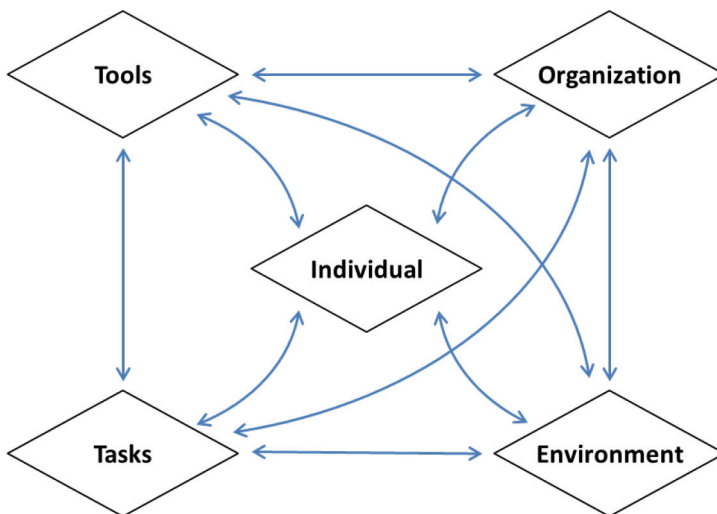
Figure 5. The work system model (Smith and Sainfort 1989).

The model has since then been complemented to encompass also the socio-organizational context and external factors, such as standards, legislation, and economic environment (Figure 6). Besides the stress of the worker, the amended model includes worker performance, job satisfaction as well as worker health, safety, and well-being (Carayon and Smith 2000, Carayon et al. 2015).
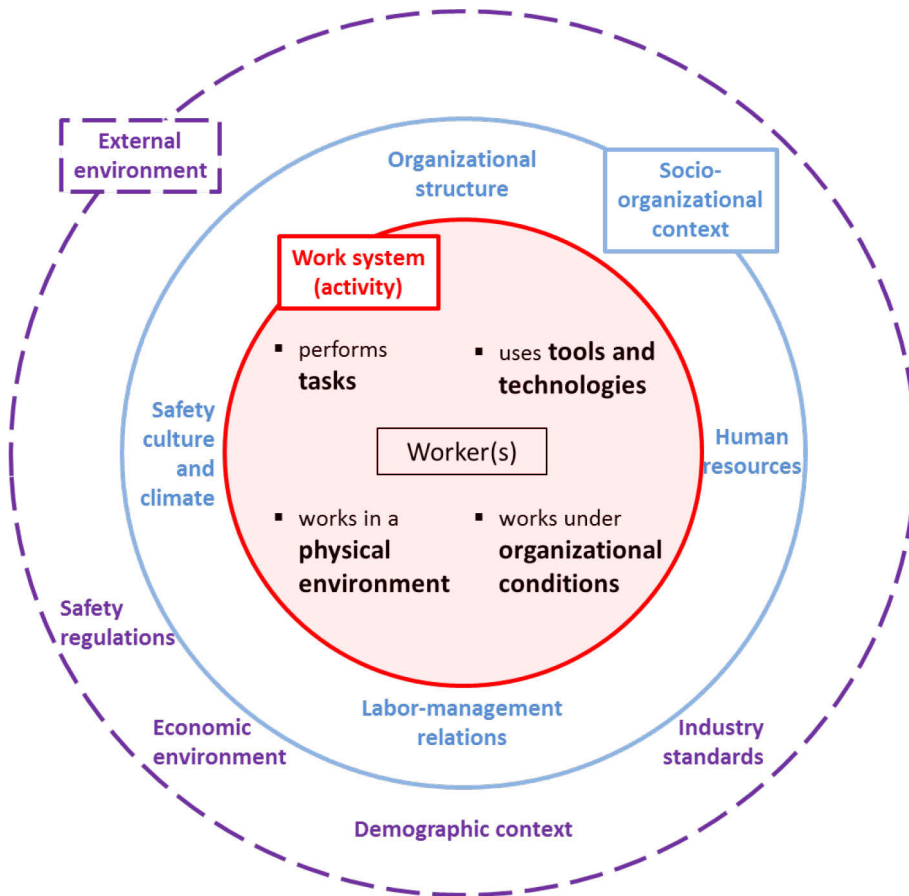
Figure 6. The model of sociotechnical system for workplace safety (Carayon et al. 2015).

The model by Carayon et al. (2015) has much in common with the socio-ecological model (SEM) that describes the influences of the social context on human development and behavior. The individual is at the core of the model, with social ecological context actors and influences placed around the core as a set of concentric circles. The closer the actor or influence is to the individual, the bigger the influence (Lee et al. 2017).

When discussing safety at work, it has become evident that the work context has to be given a broad interpretation. The work system, the socio-organizational context, and the external environment formulate a system of interactions (mechanisms) and effects that influence the outcomes of OSH promotion (Hasle et al. 2014).

2.6. Human behavior

Non-safe human behavior, such as violations of safety procedures and risk-taking, have been recognized to be major factors in the etiology of occupational accidents (Reason 1990, Salminen and Tallberg 1996, Feyer et al. 1997, Reyes et al. 2015). While the cau-

sality of accidents is complex (Rasmussen 1990, Hollnagel 2016), there is a need to understand human behavior from both safety risk assessment and risk treatment perspectives. Various models and concepts to predict and change human behavior have been developed: among the most referred are the theories of the Three Term Contingency (or ABC) Model (Ellis 1962, Skinner 1965), the Theory of Reasoned Action (Fishbein and Ajzen 1975) and the Theory of Planned Behavior (Ajzen 1991).

All these theories, models and related assessment methodologies, when applied to the domain of human safety and health, strive to establish the complicated chains of effects to explain human behavior and to identify and operationalize factors (antecedents) that lead to non-safe or safe behavior – including the feedback loop, i.e. the reciprocal effects of consequences of the behavior to antecedents and, ultimately, future behavior (Figure 7).
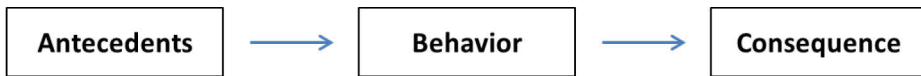
Figure 7. The ABC model (according to Ellis 1962 and Skinner 1965).
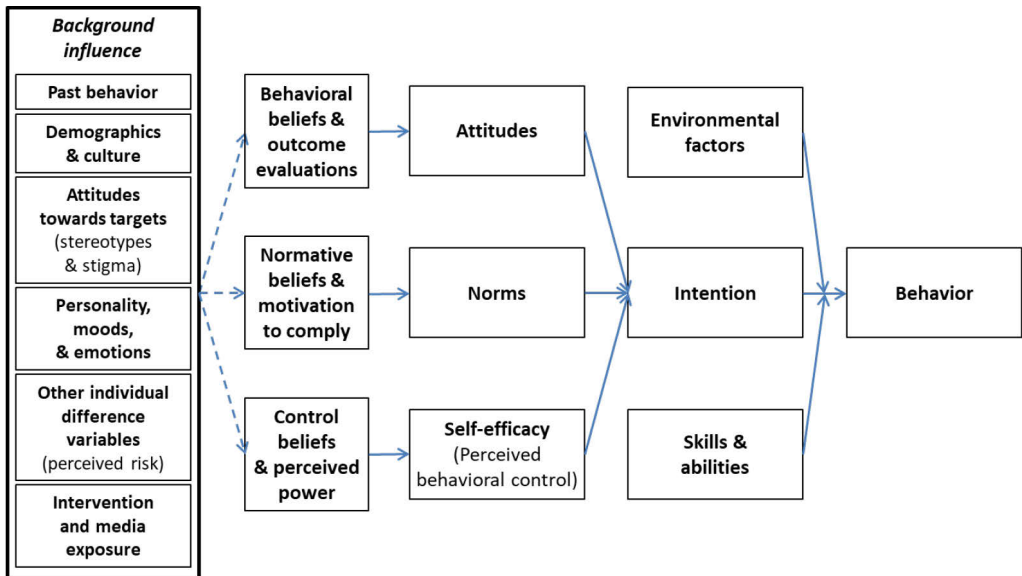
Fishbein and Cappella (2006) proposed an integrative model that describes a framework for a set of determinants (antecedents) of behavior (Figure 8). The framework comprises three central control constructs that affect the intention to perform a behavior: attitudes towards performing the behavior, perceived norms about performing the behavior, and experienced self-efficacy to perform the behavior. The intention can be masked (i.e. modified or canceled) due to environmental factors, skills and abilities that limit the behavior.

According to Fishbein (2000), the control constructs are affected by underlying beliefs that are based on considerations on behavior and its outcomes (attitude control), contemplations on normative beliefs and willingness to comply to them (normative control), and perceptions of one's capacity to execute behaviors. In the model, beliefs are formed and influenced by several background factors, such as past behavior, cultural and personal traits, and exposures to e.g. various media content.

Safety climate on a workplace has been validated to be a strong determinant of both positive and negative safety outcomes (DeJoy et al. 2004, Zohar 2010). Zohar (1980) defined safety climate as a "shared employee perceptions about the relative importance of safe conduct in their occupational behavior". The concept of safety climate considers safety in a social, shared setting inside an organization. It involves assessment of shared perceptions of the real (experienced) priority of safety in the organization. This prioritization is operationalized in the organization's policies, procedures, and practices. The factors affecting safety climate thus extend to all levels of the organization (Zohar 2014).

The Behavior Based Safety (BBS) approach applies human behavior models to all stages of safety risk management and builds on the ABC principle. A starting point of

BBS is that it places assessment, evaluation, and control of at-risk behaviors in a work-place into the hands of the persons working in the workplace, thus empowering them with "ownership" of the safety management practices (Pettinger 2000). This continuous process reinforces behavioral control which, according to the Theory of Planned Behavior, can have a positive effect on both safety related intentions and behaviors.

Figure 8. The integrative model of behavior (Fishbein and Cappella 2006).

2.7. Occupational safety and health interventions

OSH interventions can be defined as deliberate (Dyreborg et al. 2011) targeted activities and initiatives (Micheli et al. 2018) having the ultimate aim to promote safety and to mitigate injuries and negative economic implications of incidents in the workplace (Kristensen 2005). OSH interventions thus are an essential part of safety risk treatment in the risk management process.

Interventions have characteristically three phases: design, implementation, and control of effectiveness (Micheli et al. 2018). The design of interventions is based on the need to change the status quo of OSH in a selected target group or setting involving a target group (e.g. farmers or fishers). Key issues to identify during planning and design of interventions are the intervention target context, key risks and hazards, effective means to address them, potential barriers to implementation and adoption of the intervention, and other possibly critical factors (Lovelock and Cryer 2009).

The selected approach and tasks are then implemented, and the impacts are followed either during or after the intervention. The control or follow-up, i.e. the assessment of the effect, is done by considering the changes in the outcomes of the exposed group or in the working environment. These outcomes can include variables describing

changes in safety attitudes and behavior, knowledge, physical or social working environment, or incidents (near misses and accidents).

According to the program theory (Rogers 2008, Pedersen et al. 2012, Masi et al. 2014, Micheli et al. 2018), consideration of intervention mechanisms ("relevant personal characteristics of key actors or interpersonal relations between them", Pedersen et al. 2012) and intervention context ("factors that are not directly related to the performance or to behavior of the workers, but that are expected to influence the performance or the behavior substantially", Masi et al. 2014) are key for the intervention to have an effect and produce the targeted outcome (Figure 9).
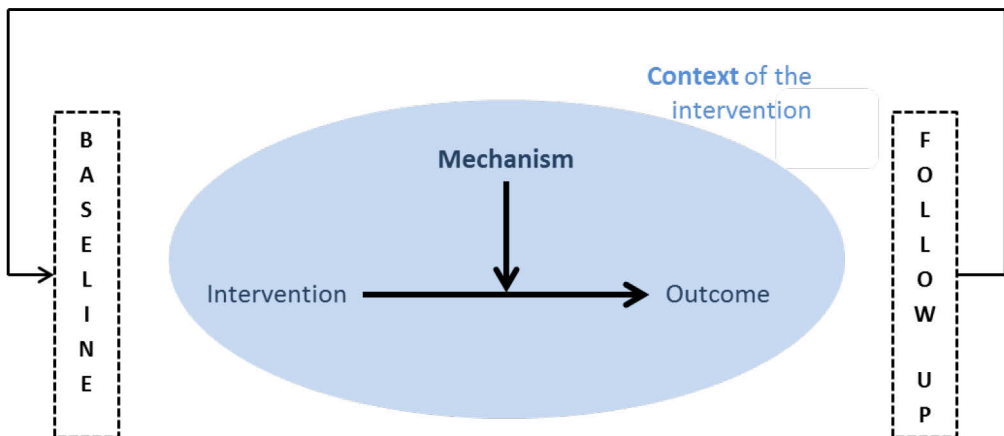
Figure 9. General model of occupational safety and health interventions (modified from Pedersen et al 2012).

The safety intervention context was modeled in [II] with farmers and the farm context having central focus (Figure 10). The created model amends the general model of OSH interventions presented in Figure 9 with elements adopted from user research. Knowing and understanding the intervention target population is especially important for successful OSH interventions (Anyaegbunam 2007). The aim of the farmer / farm context model (Figure 10) was to stress the importance of the interfaces of the intervention cycle (the outer rim in the model) with the intervention target, i.e. the farmer and the farm context. For the intervention to be feasible and effective, reliable and valid information of the intervention context should be acquired at all stages: progress indicators (i.e. status quo of occupational safety), characteristics and needs of the target group, intervention characteristics and mechanism, and changes in behavior and environment.

Intention
to intervene
with the situation

Impulses
- External, e.g. EU legislation
- Observed OSH problems
- Surveillance data
- Needs for change

Initiation of an intervention
- Program ideas
- Funding
- Pilot studies

Progress
indicators

Farmer

Farm

Context

**Changes in
behavior and
environment**

Results
of the intervention

**Characteristics
and needs of
the target group**

Development
of the intervention
- Goals
- Approach
- Communications channel

Intervention
characteristics
and mechanism

Implementation
of intervention

Figure 10. Conceptual model of the safety intervention context in agriculture [II].

The essential questions needing an answer during the design, implementation, and control of interventions are [II]:

1. What characteristics and needs of the [intervention] target group should be recognized and served?
2. How can knowledge of these factors be used to formulate an effective intervention approach?
3. What kind of accessibility, attractiveness, and utility value does the intervention represent to the farmer?
4. What factors and background variables affect the data that are used to assess safety and health status and progress on farms (i.e. the "results of intervention" and "progress indicators" in the conceptual model)?

The options for treating OSH risks have been presented in a hierarchy based on their efficacy in exposure to hazards (Figure 11, NIOSH 2019). The four main types that interventions address comprise behavioral, organizational, psychosocial, and engineering changes (Kristensen 2005).
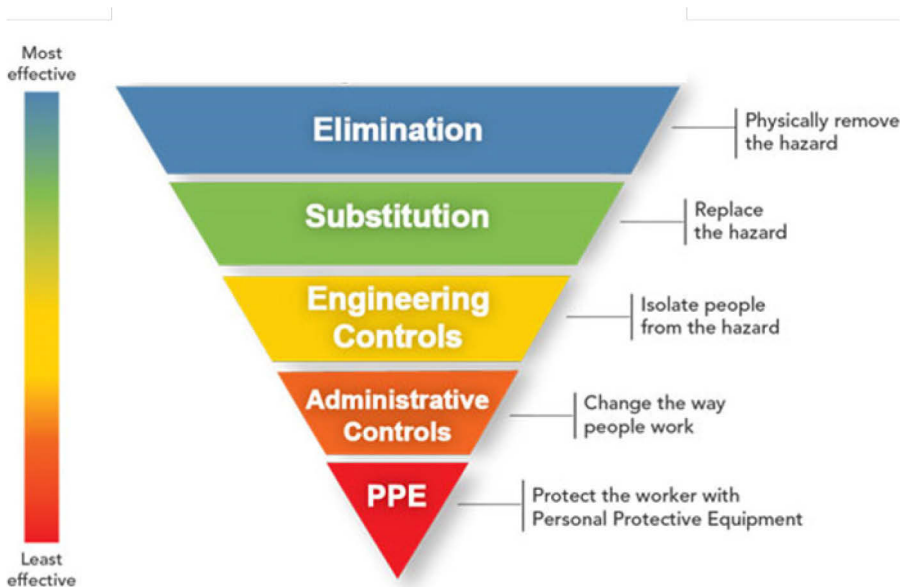
Figure 11. The hierarchy of controls to prevent hazardous exposures (NIOSH 2019).

While recorded accidents along with context data facilitate the quantitative analysis of occupational accident intervention efficacy, they are in most cases too rare to reach statistical significance in a typical Randomized Control Trial setting (DeRoo and Rautiainen 2000). Lack of valid data to assess the true number of accidents and thus the effect of interventions was also pointed out by Pedersen et al. (2012). Besides the number and changes in incidence rate of accidents, also other outcomes have been measured to assess effect of risk treatment initiatives. These comprise changes in safety knowledge, attitudes, behavior (DeRoo and Rautiainen 2000), safety climate and culture (Smith-Crowe et al. 2003, Zohar 2014, Jiang et al. 2018) as well as near misses (Gnoni and Saleh 2017).

When assessing the implementation and efficacy of interventions, with the aim of developing ever more effective ones, it is important to distinguish between two possible causal factors to intervention not being as effective as planned: 1) implementation failures and 2) theory failures (Pedersen et al. 2012). Implementation failures refer to the ways the intervention is executed (the "nuts and bolts" of the "vehicle for change") while theory failures point to errors in the logic of how the intervention is supposed to affect the intended safety outcome. For the intervention to be effective, both factors must also take the local context into account (Chandler et al. 2016).

2.8. Occupational safety and health determinants

The Merriam-Webster online dictionary (https://www.merriam-webster.com/) defines the noun 'determinant' as "an element that identifies or determines the nature of something or that fixes or conditions an outcome". According to the same source, some

of the synonyms or near synonyms of 'determinant' include "factor, antecedent, cause, reason, impetus, and inspiration". In the domain of OSH, the outcomes concerned may be the harmful incidences (injuries, illnesses, property damage), but also intermediary effects in the accident causation and prevention functions, such as the number of near-misses, safety performance, or level of safety knowledge.

The determinants of OSH, with regard to the above definition, are often called e.g. causes, risk factors, predictors, antecedents, barriers, etc. in literature (Table 2), and their research scope and theoretical approach to safety vary.

In a literature study concerning determinants of safety outcomes and performance in four high-risk industries, Cornelissen et al. (2017) compiled five independent and two dependent clusters related to occupational safety. The clustering is based on a bottom-up analysis of reported relationships between individual dependent and independent factors of safety. The factors were subsequently categorized, based on similarity, to create the summary clusters shown in Figure 12. The five clusters and corresponding underlying safety determinants reflect factors that have been reported to affect safety related performance and outcomes in the original subject industries, but they can also be used to identify and categorize additional safety determinants for other industries. Other, more specific categorizations of occupational safety related factors exist e.g. with respect to components of the work system (Smith and Sainfort 1989, Carayon et al. 2015), human behavior (Fishbein and Cappella 2006), or factors affecting transition of interventions to OSH outcomes (Micheli et al. 2018).

Table 2. Occupational safety and health determinants and corresponding concepts in previous studies.

Determinant or corresponding concept	Examples	Source
Determinants		
… as a synonym for predictor	Employment duration, exercising, health problems	Pietilä et al. (2018)
… of OSH/related behavior	Attitudes, social norms, behavioral intention	Colémont & Van den Broucke (2008)
… affecting events and behavior that lead to injuries	Organizational design, individual characteristics, risk perception	Hagberg (1997)
… of safety performance; "predictive nature"	Job demands, job control, social support	Turner et al. (2012)
… of safety culture	Training, inspections, safety achievement recognition	Risch et al. (2014)
… of safety outcomes and performance	Physical working environment, employee demographics, governmental bodies	Cornelissen et al. (2017)
… of safety climate	Demographics, environmental conditions, safety policies and programs, organizational climate	DeJoy et al. (2004)
… of safety performance factors	Procedural knowledge and skills	Burke et al. (2002)
… of injuries on farms	Number of different types of machines	Suutarinen (2003)
… of machine/related injuries	Machinery age, presence of safety devices, amount of time committed to conduct routine maintenance	Narasimhan et al. (2010)
… of safety performance	Knowledge, skills, and motivation to perform	Zohar (2014)
… of critical outcomes	Safety, profitability, sustainability	Robertson et al. (2015)
… of workplace OSH practice	EU Directives, labor inspection, social dialogue	Walters et al. (2013)
Barriers		
… and promoting factors	Personal characteristics, limited resources, ease of safety measure implementation, enforcement	[II]
… to safety	Rush, tiredness and fatigue, peer pressure	Lovelock and Cryer (2009)
… to implementation of interventions	Expenses, lack of suitable protection, inconvenience of acquisition and installation	Lilley et al. (2009)

Causes		
… of work injuries	Tractors, cattle, buildings	Virtanen et al. (2003)
… of accidents pointed by fishermen	Inattention, carelessness, ship movements, slipperiness	Thorvaldsen (2013)
… and circumstances of an accident	Working environment, deviation, contact mode of injury	Eurostat European Commission (2013)
Predictors		
… of general safety attitudes	Personality, level of experience, level of stress, attitudes, environmental stress	Irwin and Poots (2018)
… of injury (psychosocial)	Perceived economic problems, stress symptoms, safety considerations during investments, farm size	Glasscock et al. (2006)
… for occupational injuries and diseases	OH services membership, gender, mother tongue, income level	[III]
Risk factors (or 'factors')		
… and exposures on farms	Ergonomic and psychosocial factors, work organization	Cryer et al. (2009)
… of injury	Male gender, older age, livestock production, larger income and operation size	Leppälä (2016)
… of safety climate	Leadership, organizational, and worker factors	Nielsen and Mikkelsen (2007)
Antecedents		
… of safety behavior	Safety signs, education, rules and policies	Byrd (2007)
… of safety performance (knowledge and skill-related)	Training experience, knowledge and skill measures	Burke et al. (2002)
… of safety performance	Safety knowledge and motivation, conscientious-ness, propensity for risk taking, work pressure	Christian et al. (2009)
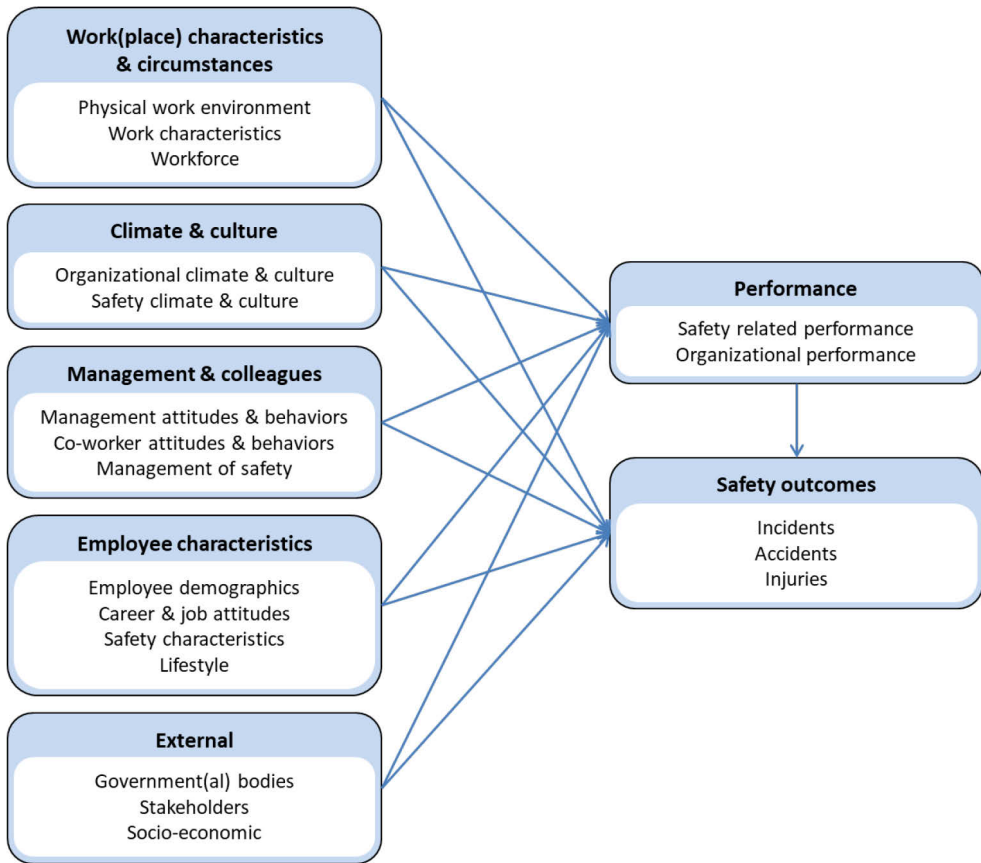
Figure 12. Occupational safety related clusters and their associated categories (Cornelissen et al. 2017).

The specificity of the determinants (as a concept) ranges from a single direct cause (e.g. chemical agent causing injury) at the sharp end (Subchapter 2.3, Figure 3) to complex, external context factors (e.g. regulations affecting work execution) at the blunt end. Both the sharp and the blunt ends have been dealt with in scientific literature as being determinants of occupational accidents (Hollnagel 2016, Cornelissen et al. 2017). They are in many ways interrelated and formulate chains of effects leading to performance and safety outcomes (Schulte et al. 2012).

"Hard" evidence comprising both causal and statistical relevance of determinants of accidents or accident prevention success has proven to be difficult to establish (e.g. Murphy et al. 1996, DeRoo and Rautiainen 2000, Nielsen and Mikkelsen 2007, Lehtola et al. 2008, Lilley et al. 2009, Lovelock and Cryer 2009). Single causal factors and factor combinations are found in regular accident analysis, but comprehensive etiology also being useful for shaping preventive actions is tedious to assemble. Still, the collected information, even if incomplete, can guide decisions on prevention and further knowledge needs (Runyan 1998).

Previous accidents as such are self-determining (Karttunen 2014) when looking from statistical correlations point of view. In that sense, they should also be called determinants. The focus in this thesis is, however, on the factors contributing to accidents (etiology of injuries) rather than factors explaining accidents (epidemiology of injuries), although both approaches benefit from the purpose of relating determinants to occupational accidents.

2.9. Summary of models and concepts

In the domain of this thesis, safety and health at work (discussed in Subchapter 2.1) are the ultimate goals. The risk management process (Subchapter 2.2) provides the framework and defines the two core stages of how to reach these goals. Risk assessment (Stage 1) comprises research dealing with accident causation (Subchapter 2.3), whereas risk treatment (Stage 2) involves various approaches to mitigate risks and promote occupational safety and health (OSH interventions, Subchapter 2.7). The concepts of the work system and related social context (Subchapter 2.5) define factors that describe the context of occupational accident and disease incidents and simultaneously comprise factors that describe the intervention context. Human behavior (Subchapter 2.6) is a central factor of the socio-ecological work system and, consequently, a critical factor to be considered during accident analysis and prevention. In Subchapter 2.8, the concept of occupational safety determinants was introduced and defined in relation to synonyms and near synonyms used in relevant literature.

The compilation of models and concepts in the preceding subchapters approach occupational safety – the core domain of this thesis – from various viewpoints and disciplines. Multi-disciplinarity is necessary when dealing with OSH assessment and accident prevention (Mykletun 2000, Lamm et al. 2007, Sethi 2010, Pillay 2015, Chang et al. 2016, Lee et al. 2017). Concepts and models are useful tools in creating a framework to discuss safety and safety promotion (Maurice et al. 1998), but they do include preconditions on how they can or should be applied to make valid conclusions. These limitations may be due to factors like the original purpose of the model (the establishment of a theory vs. the procedural description of an application), context specificity (the domain or industry of an application) or epistemology (the origins of the embedded knowledge), on which they are built on.

Concluding from the above discussion on concepts and models, knowledge of factors relevant to both risk assessment and risk treatment is essential for effective promotion of occupational safety. While models and concepts are criticized for various reasons (Olson and Zanna 1993, Toft et al. 2012, Hollnagel et al. 2014, Grant et al. 2018), they all add to the pool of relevant factors to be considered. These factors include proximal and distal causal and contributing factors of an accident (in the risk assessment phase) as well as work system related and human factors that contribute to the logic of translating interventions into positive safety outcomes (in the risk treatment phase).

All these factors are called "determinants of occupational safety" in this thesis.

The arguments supporting this rather broad definition of the concept of occupational safety determinants are as follows:

1. The causality of occupational accidents, according to current paradigms, is complex (Groeneweg 1994, Suraji et al. 2001, Khanzode et al. 2012, Thorvaldsen 2013), and a multi-disciplinary approach is needed for assessment and interpretation of accident causality.
2. Both predictive (modeling) and post hoc assessment of accident causality and hazards as well as identification of contributing and modifying contextual and human factors to successful interventions involve consideration of a broad set of influencing factors.
3. In Finnish agriculture and fisheries as well as in most other micro and small enterprises, risk management and treatment measures are implemented in the same context (in broad terms) and engage the same people who are also potential victims of accidents in that context. Proximal and distal determinants of accidents thus resonate and overlap with the work system and context specific determinants embedded in the logic of translating interventions to positive safety outcomes.

3. Objectives and outline of thesis

The ultimate goal of this thesis is to facilitate the formulation and implementation of effective preventive measures for mitigating occupational accidents in primary food production. This goal is pursued by assessing and gaining understanding of determinants of occupational safety, their assessment methods and contribution to safety risk management using two occupational safety research projects related to Finnish agriculture and two related to Finnish commercial fishing (Eurostat NACE categories 2.A.1 and 2.A.3.1, respectively) as study cases. The case industries were selected due to their high injury rates. Additionally, Finnish farms and fisheries are mostly family owned small scale enterprises (OSF 2019a, OSF 2019e) whose statutory accident insurance, pension insurance, and occupational health services are administered by the same entity, the Finnish Farmers' Social Insurance Institution (Mela).
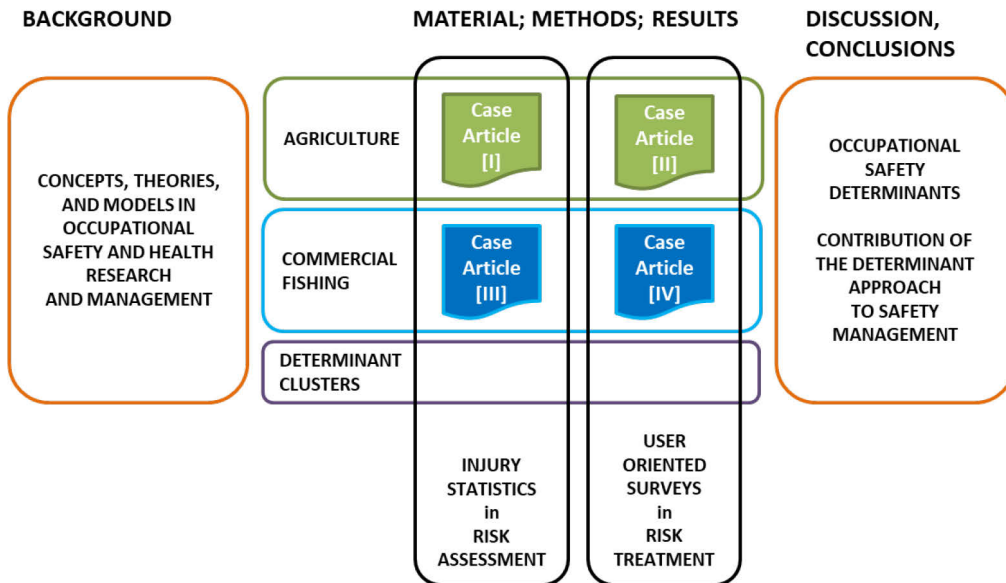
In this thesis, information on factors that contribute to occupational safety are approached from a methodological viewpoint. The thesis uses the risk management process (ISO 2018b) as a theoretical framework, inside which contemporary theories, models, and concepts related to occupational safety are discussed. The central concept of occupational safety determinants defined in Subchapter 2.9 is used to study sources and assessment methods of information that is needed during occupational safety risk assessment and risk treatment. The focus of this thesis is thus on accidents causing physical occupational injuries and potential material losses, and accident prevention. Occupational diseases are not discussed.

By combining results of both accident and intervention research involving multiple methodological approaches, this thesis broadens the spectrum of factors to be considered during safety management beyond the results of single, isolated studies. A list of occupational safety determinant clusters is composed to facilitate structured assessment of occupational safety determinants.

Specific aims of this thesis research are

1. to compose a list of occupational safety determinant clusters to be used for organizing and further discussion of the determinants derived from the study cases [I–IV]
2. to derive occupational accident related determinants using data from accident claims records (risk assessment approach), [I] and [III]
3. to derive work system and context related occupational safety determinants that affect the success of occupational safety interventions using user centered survey and interview materials (risk treatment approach), [II] and [IV]
4. to assess the contribution of the derived determinants to occupational safety management.

The composition of this thesis along with the contribution of the included original articles [I]–[IV] are shown in Figure 13.

BACKGROUND **MATERIAL; METHODS; RESULTS** **DISCUSSION, CONCLUSIONS**

CONCEPTS, THEORIES, AND MODELS IN OCCUPATIONAL SAFETY AND HEALTH RESEARCH AND MANAGEMENT	AGRICULTURE	Case Article [I]	Case Article [II]	OCCUPATIONAL SAFETY DETERMINANTS
	COMMERCIAL FISHING	Case Article [III]	Case Article [IV]	CONTRIBUTION OF THE DETERMINANT APPROACH TO SAFETY MANAGEMENT
	DETERMINANT CLUSTERS			
		INJURY STATISTICS in RISK ASSESSMENT	USER ORIENTED SURVEYS in RISK TREATMENT	

Figure 13. Thesis composition and contribution of the original articles to the thesis research.

The aim of this thesis study is to assess and gain understanding of determinants of occupational safety, their various assessment methods as well as their contribution to safety management. The selected approach, involving use of four study cases to derive the determinants, does not however facilitate compilation of a comprehensive set of determinants related to occupational safety and health of Finnish farmers and commercial fishers.

Mental stress and fatigue that affect welfare at work, work ability, and work satisfaction of Finnish farmers and fishers has gained more attention during the current decade. The Finnish Farmers' Social Insurance Institution (Mela) has been active in developing various approaches to intervene with the observed high mental stress levels among these target groups. The etiology, epidemiology, consequences, and prevention of mental stress are outside the scope of this thesis.

4. Materials and methods

The occupational safety determinants derived in this thesis study originate from the original articles [I–IV] that are described in more detail in Subchapter 4.1. Principles of derivation of occupational safety determinants as well as the composition of the list of occupational safety determinant clusters are presented in Subchapter 4.2. Methods and data used in the included original articles are described in Subchapters 4.3 to 4.6.

4.1. Study cases

A summary of the original data sources, methods of occupational safety determinant derivation, and use of the original article results in this thesis study is presented in Table 3.

Table 3. Data sources, methods of determinant derivation, and use of the included original articles [I–IV] to reach the objectives of this thesis study.

Original article(s)	Data source(s)	Methods of safety determinant derivation	Use of results in this thesis study
I	Injury claims records of Finnish farmers (n=6,414) from 1992–2002	Descriptive statistics Phrase analysis Conceptual modeling	Retrospective assessment of safety determinants, based on injury claims records of farmers (Thesis objective 2)
III	Insurance history data of all Finnish insured commercial fishers (n=1,954) and injury claims records (n=844) from 1996–2015	Descriptive statistics Statistical modeling	Retrospective assessment of safety determinants, based on injury claims records of commercial fishers (Thesis objective 2)
II	Notes from semi structured theme interviews (n=11 farmers) and focus group discussions (n= 9 farmers)	Topical analysis and grouping of interview materials	Prospective assessment of safety determinants, based on farmers' views on barriers and drivers of safety interventions (Thesis objective 3)
	Cultural probe materials (diaries and photos) of 9 farmers	Topical analysis of probe materials followed by affinity analysis and collaborative result validation. Conceptual modeling	

IV	Structured interview data of 10 Finnish and 37 other Nordic commercial fishers	Descriptive statistics and variance analysis of scorings of safety measure importance	Retrospective and prospective assessment of safety determinants regarding adoption of interventions (Thesis objective 3)
I–IV	All of above	Composition of the list of occupational safety determinant clusters, and assessment of the information content of the determinants with respect to occupational safety risk assessment and risk treatment (Thesis objectives 1 and 4)	

Article I is based on occupational injury compensation claims data acquired from the Finnish Farmers' Social Insurance Institution (Mela). It comprised data on slip, trip and fall (STF) injuries that occurred in Finnish dairy, beef, and swine production, and that were caused by a floor structure. Factors associated with these injuries were analyzed, with special attention to factors related to the built environment, especially floors. The building performance model was used as a conceptual framework for the analysis. In the framework of safety risk management, Article I represent risk identification in the risk assessment phase. It had a specific contextual scope, hazardous floor structures, and the intention to identify additional contributing risk factors. Causality was presumed based on the injury compensation claims data classification of primary injury cause. The chains of effect of found risk factors to injuries were hypothetical and based on models of STF injury mechanisms and building performance evaluation.

Article III is a retrospective cohort study focusing on compensated occupational injuries, diseases and insurance history of Finnish commercial, self-employed fishers. Utilizing the insured population data and corresponding compensation claims data acquired from Mela, univariate and multivariate generalized linear mixed models were used to determine predictors of occupational injuries. Article III relates to the risk analysis phase of risk assessment. It established statistical correlations of common contributing and background factors to injuries. The chains of effect of the found factors to injuries were hypothesized but not verified. The statistical data in [IV] includes both occupational injury and disease claims, but the share of occupational diseases is only 4.5% or 41 cases, so they do not introduce a significant bias to the extraction of occupational safety determinants in this study.

The aim of Article II was to identify factors affecting the adoption and implementation of safety information. Article II is based on material originating from two studies. The first study materials comprised notes and recordings made by the research group during interviews on 11 farms that had recently had a fire in an animal confinement. The second study materials included cultural probe materials (the method is described in Subchapter 4.3) as well as notes and recordings made by the research group during

group discussions with 9 Finnish farmers. The choice of addressed safety hazards in the second study was free, although the significance of machine and building maintenance related safety risks was emphasized during the initial briefing for the self-documentation phase. Article III assesses the work system, contextual factors, and human behavior related to efficacy of the risk treatment. It utilized methods of human factors research (user-oriented surveys) to assess socio-technical context factors. Hypothetical causalities between identified safety risk factors and behaviors that affected their persistence (intervention barriers) or removal (enabling factors to interventions) were created.

Article IV is based on a Nordic survey that focused on commercial fishers' opinions on what occupational safety measures are effective ("What works?"). Structured interviews were done with 47 fishers in Finland (n=10), Norway (n=10), Iceland (n=7), Denmark (n=10), and the Faroe Islands (n=10). Fishers were asked to rank 13 preselected occupational safety measures on a scale from 1 (little/no importance) to 10 (great importance) concerning their experienced effectiveness. In Article IV, risk treatment efficacy is assessed using a user-oriented survey. Hypothetical causal factors for the user assessments on efficacy and their variation between countries were established based on socio-technical and socio-ecological context models.

4.2. Determinant derivation and clustering

Main characteristics of the determinants, based on the summary definition of occupational safety determinants in Subchapter 2.9, are

1. They are factors included in
   a. models and theories related to safety risk assessment, prediction, or treatment
   b. the results and discussions of research papers in corresponding topics
2. They are proximal or distal factors in the cause to effect chain, or associated factors without established causality to accidents or intervention efficacy (i.e. nonbehavioral risk factors related to demography and farm characteristics, Van den Broucke and Colémont 2011).

These characteristics were used as criteria for extracting the determinants from the study cases [I–IV]. In the first phase, 98 determinants or determinant phrases (e.g. "animal transport or care") from the results, and 112 determinants or determinant phrases from the discussion parts of the studies were extracted. Using the affinity analysis consolidation method (discussed in Subchapter 4.3), 67 single determinants could be identified.

To facilitate further consolidation and discussion of the determinants derived from the study cases [I–IV], a comprehensive classification of OSH determinant clusters was required. The theories, concepts and models related to accident causation, the work system, human behavior, and OSH interventions use multiple different categorizations

of occupational safety determinants. Some of these categories comprise management (Swiss Cheese Model, Reason 1990), task and technology (Balance Theory of Work, Smith and Sainfort 1989; Socio-technical System for Workplace Safety, Carayon et al. 2015), attitudes and behavior (Integrative Model of Behavior, Fishbein and Cappella 2006), and barriers to interventions (Pedersen et al. 2012, Micheli et al. 2018).

No single categorization alone covered the topics of the derived determinants of the study cases [I–IV]. Thus, various combinations of existing categorizations were tried by iteratively populating them with the derived determinants. At this point, the concept of "occupational safety clusters" was introduced to denote the list of combined determinant categories. The concept of clusters was earlier used by Cornelissen et al. (2017) in the same context and for identical consolidation purposes.

The five elements of the work system model, initially described by Smith and Sainfort (1989), were first chosen for determinant cluster headings. They represent both the "work context" in which accidents occur, the "intervention context" that should be considered when designing and implementing OSH interventions as well as human factors effective in both safety risk assessment and treatment. Later research has included "external factors" to the list of factors affecting safety (Pettinger 2000, Hale et al. 2010, Ko et al. 2010, Carayon et al. 2015, Cornelissen et al. 2017). These include e.g. public governance, inspections and socio-economic factors.

Safety performance has been defined as a set of safety and well-being promoting actions and behaviors that repeat consistently across various jobs (Burke et al. 2002). As a concept, it reflects the efforts of the work system to maintain and promote a certain level of safety at work. Thus, it is an outcome from the perspective of interventions. At the same time, it acts as a determinant for unwanted safety outcomes like close calls, accidents, and injuries. Safety performance also contributes to organizational performance (Smith-Crowe et al. 2003, Fernández-Muñiz et al. 2009). Consequently, to a combination of these, "Performance" was added to the list of determinant clusters by Cornelissen et al. (2017).

To also include determinants that specifically affect design and implementation, and thus the outcome of interventions (including all "non-formal" efforts for safety risk mitigation), the concepts of intervention mechanisms as well as intervention barriers and drivers were added to the list of determinant clusters. The third intervention related concept, the "intervention context" (Micheli et al. 2018) is overlaps with the "Work context" factors and was consequently not included to the list of determinant clusters as a separate item.

The final compiled list of occupational safety determinant clusters is based on a combination of 1) the concept and factors of the work system established by Smith and Sainfort (1989) and amended by Carayon (2009), 2) the OSH determinant clusters established by Cornelissen et al. (2017) in a systematic literature review of determinants of occupational safety outcomes, and 3) the components of the model of transition of OSH interventions into OSH outcomes (Micheli et al. 2018).

The complete list of occupational safety determinant clusters composed in this thesis study to facilitate the structured assessment and discussion of safety determinants is presented in Table 4. It shows the main cluster titles to which the derived determinants from Articles [I–IV] were assigned for further contemplation. The table also displays examples of determinants by cluster. Minor adjustments that were made to join overlapping clusters and to provide coherent cluster naming are shown in the footnotes of Table 4. The clusters are described in more detail in the text following the table.

Table 4. List of occupational safety determinant clusters with examples determinants and original sources of the cluster concepts.

Determinant cluster	Examples of determinants included	Original sources of cluster concepts
Physical environment	Design, layout, environmental conditions	Balance Theory & Work System Model (Smith and Sainfort 1989, Carayon 2009)
Organization and management *)	Strategic and operative decisions, personnel management, organizational support, safety culture	
Individual	Demographic, physical and psychological characteristics; perceptions, attitudes, behavior, skills, motivation	
Task	Physical and mental load of the task, repetitiveness, job control and significance	
Tools and technologies	Ergonomic properties of tools and technologies	
External	Rules and regulations by governing bodies and stakeholders; socio-economic factors	Determinants of safety outcomes and performance (Cornelissen et al. 2017)
Performance	Use of personal protective equipment, safety compliance Economic performance	
Intervention mechanisms **)	Perceived importance of intervention, resistance to change, self-confidence	Transition of OSH interventions to safety outcomes (Micheli et al. 2018)
Intervention drivers and barriers **)	Topical interaction with peers, practicality of the intervention; Lack of time and resources	

*) Originally Organization (Smith and Sainfort 1989); "Management" was added to better correspond to the commonly quite simple organization structure on in Finnish farms and fisheries. Thus, also the clusters "Climate & Culture", and "Management & Colleagues" presented by Cornelissen et al. (2017) were merged into this cluster.

**) Originally "Mechanisms", "Drivers" and "Barriers" (Micheli et al. 2018); "Intervention" was added to avoid confusion with the concepts of injury mechanisms and safety barriers (safety filters, Subchapter 2.3).

Safety determinants in the Environment cluster include factors of the physical environment. These include design and layout of the workplace as well as environmental

conditions like temperature, vibration, and lighting (Smith and Sainfort 1989, Carayon 2009). These determinants correspond to the "Conditions" layer of the traditional Swiss Cheese Model (Reason 1990) and were a main subject of investigation in [II].

Organization and management affect safety by shaping work arrangements and scheduling of work as well as providing social and organizational support (Smith and Sainfort 1989, Carayon 2009). They also play a major role in development of safety climate and culture in the organization (Cooper 2000, Fernández-Muñiz et al. 2007, Zohar 2014). The "Organization and Management" cluster relates to determinants in the sociotechnical and social ecological models of organizations as well as to those in the "Management Systems" layer in the Swiss Cheese Model (Reason 1990). "Climate & Culture" and "Management & Colleagues" clusters proposed by Cornelissen et al. (2017) were merged into the "Organization and Management" cluster due to the relatively shallow organization structure on Finnish farms and fisheries.

Individual characteristics of a person determine how other safety related factors affect physical and mental safety. They do so both by modifying the effect of work stress and strain on the individual, but also by affecting safety performance of the individual and the group (Smith and Sainfort 1989). The "Individual" cluster relates to the theories of human behavior and comprises determinants that are included in e.g. the integrative model of behavior (Fishbein and Cappella 2006).

Job task properties comprise both physical factors like workload, strain and repetitiveness, and mental factors like job control, challenge and significance (Carayon 2009). The effects of determinants in this cluster are mediated via the human involved, affecting behavior and medical health status. Information about tasks and related tools and technologies (as discussed below) is essential for establishing causality because they are active elements in the sharp end of the causation chains of effect.

Tools and technologies comprise the means of accomplishing tasks. They often determine the load that may compromise the safety of the individual (Smith and Sainfort 1989). When operated by humans, it is important to consider ergonomic factors and usability of designs of tools and technologies to ensure safety and health of operators (Carayon 2009).

External determinants encompass factors of safety that have their origin outside the organization. Mandatory laws and regulations, opinions and needs of interest groups as well as direct and indirect economic implications have been recognized to influence negative safety outcomes (Cornelissen et al. 2017). Determinants in the "External" cluster relate to typical blunt end or distal factors of (linear) accident causation models and to the outer rims of sociotechnical system for workplace safety (Carayon et al. 2015).

Safety performance and organizational performance are interrelated characteristics (Fernández-Muñiz 2009) that can be linked to both organizations and individuals. Safety performance encompasses factors like use of personal protective equipment (PPE), safety participation and safety compliance, while organizational performance is linked to general indicators, such as economic or environmental performance (Cornelissen et al. 2017). The "Performance" cluster summarizes safety determinants that are related to

accident causation (safety compliance), but also act as consequences of successful safety management (economic performance).

Intervention mechanisms comprise factors that together with contextual factors determine whether interventions reach or do not reach their goals. The contextual factors, when discussing interventions, correspond to the determinant clusters discussed above. Intervention mechanisms comprise "cognitive and psychological states" (Micheli et al. 2018), i.e. human factors which affect both personal and interpersonal relations (Pedersen et al. 2012). Determinants in the "Intervention mechanisms" cluster relate to factors in the human behavioral models.

Drivers and barriers to interventions are factors ("spin-offs") that significantly affect the outcome of interventions. Drivers and barriers are thus a specific subset of all contextual and human factors. Intervention drivers and barriers, together with intervention mechanisms determine the outcome of the intervention in the prevailing context (Micheli et al. 2018).
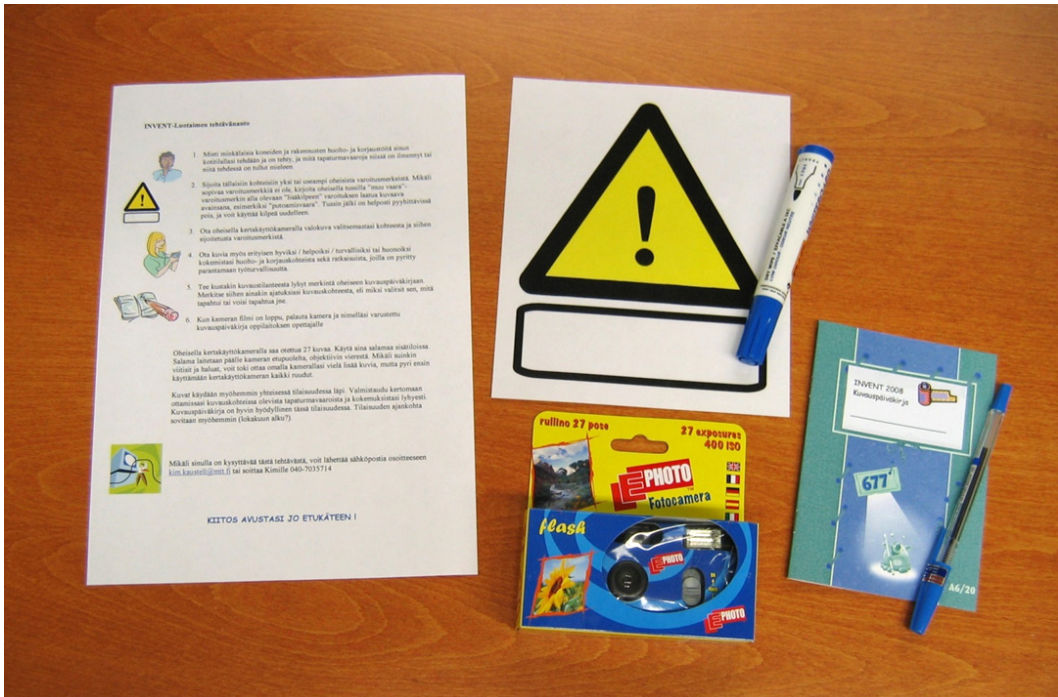
4.3. Cultural probes

The cultural probe (a.k.a. design probe) method was developed in the late 1990s. It is a user centered approach that emphasizes the user's role in creating source materials (via self-documentation) for design decisions related to products and services (Mattelmäki 2006). Cultural probes utilize methods from social sciences, such as photography, life documents, biographical interviews, and structured diarizing (Graham et al. 2007). The method has been reported to produce a "rich and varied set of materials that ... let us ground our designs in the detailed textures of the local cultures" (Gaver et al., 1999). Applied to the assessment of human behavior related determinants in occupational safety management, this kind of materials potentially produce relevant material for analyzing the attitudes, norms, and perceived self-efficacy and their antecedents. Rautiainen et al. (2012) used the cultural probe method to identify sources of physical and mental strain, fatigue, habits to cope with work and leisure, safety awareness, teamwork, social behavior, and other occupational safety related factors among foreign workers on Norwegian horticultural farms.

Mattelmäki (2006) listed two additional reasons that are relevant to the choice of this method for examining occupational safety determinants: In the first place, it focuses on the user and user's contextual environment and experiences, which are key factors of the work system and transfer of safety interventions into safety outcomes. Secondly, the cultural probes stimulate openness to express and validate interpretations between the users and the research group. Making justified interpretations of e.g. causalities and mechanisms of intervention are core tasks of accident and intervention research.

The cultural probe method applied in [II] involved 9 active and educated farmers who were selected based on their farming experience and farming related training. Methodological considerations made in the study included limiting the number of participants to about ten as well as selecting participants from a narrow geographical area to

facilitate effective group sessions. The mission of the study group was to identify and document hazards and good safety solutions on their own farms using a probe kit (Figure 14, described in detail in [II]). The task was to place a warning sign at a hazardous location, take a photo of it, and to document it using a provided notepad. Additionally, good safety solutions were to be documented using photos and the notepad. Special attention was to be paid to machinery and building related maintenance due to its frequent contribution to occupational injuries.

Figure 14. The cultural probe kit used in [II].

The collected probe material (photos and notebooks) were organized and analyzed by the research group using the affinity analysis, a method that facilitates data consolidation. Individual observations of the cultural probe data were grouped into "meaningful, self-contained parts" (Holzblatt and Beyer 2014) and consequently organized to form causal themes with regard to the research questions on how particular hazards had developed and why they continued to exist in the farm working environment. After consolidation, topical posters were created. The interpretations made by the research group were validated by presenting these posters, followed by discussions and eventual amendments during two group discussions with the farmers who participated in the probe. Finally, based on notes from these discussions and the amended posters, the research group derived barriers and promoting factors for safety improvements on the farms.

4.4. Semi-structured interviews

The semi-structured interviews were conducted with 11 Finnish farmers [II] by the research group. The studied farmers were recruited by a commonly used farm insurance company. Inclusion criteria were a fire in an animal confinement building less than six years ago as well as geographical and building type dispersion. The number of included farms was determined by the research group based on available resources and methodological considerations. The interview questions comprised questions about animal production methods, building maintenance and eventual alterations, and technical installations. Additionally, questions were asked about detection and progression of the fire, firefighting and other rescue activities as well as about adaptation to the situation after the fire had been put out. Spatial and functional information was documented by the research group into the building drawings, and the discussions were recorded. The farmer's thoughts of causality and lessons learned were also probed. The fire interviews were complemented by a walk on the farm fire premises together with the farmer, which stimulated additional discussion around fire safety issues. The gathered material from the 11 farms was transliterated and organized topically, after which conclusions were drawn by the research group.

In Study [IV], a total of 47 commercial fishers from Finland, Norway, Denmark, the Faroe Islands, and Iceland were interviewed face to face or via telephone by researchers in respective countries. The number of fishers per country was targeted at ten, based on methodological considerations made by the Nordic research group. The recruitment method was random across the participating countries. The only inclusion criterion was that the fisher had to have a career length of more than ten years. The survey questionnaire created among the research group included background questions and a list of 13 common occupational safety measures that the fishers were asked to assess according to their effect on preventing occupational injuries in fishing. Additionally, there were three open questions concerning the challenges of occupational safety promotion and most important topics to be covered.

4.5. Phrase analysis

Narratives included in the occupational injury claims data used in [I] were analyzed to detect additional information on the injury mechanism (slip, trip, or fall), and common underfoot hazards (obstacles, contaminants, and fixed structures). The injury narratives were read by two researchers and codes of the findings were added to the respective data records. A random cross-check of the resulting new coding was performed to ensure uniform coding by the researchers.

The phrase analysis approach has been used and studied by e.g. Thomas et al. (2001), Lincoln et al. (2004), Bondy et al. (2005), Mattila et al. (2008), McKenzie et al. (2010), Nenonen (2013), and Kaustell et al. (2016). Central benefits of analyzing the narratives are that it facilitates additional case coding, detection of specific accident related

elements, and it may also contribute to capturing information on the sequence of events (McKenzie et al. 2010).

4.6. Statistical data and analyses

The Finnish Farmers' Social Insurance Institution (Mela) administers statutory accident insurance for farmers and fishermen (Mela 2019b) and collects statistical data of the insurance history and accident claims of the insured population. The accident claims data is recorded according to the ESAW guidelines (Eurostat European Commission 2013) with complementary, more detailed information of the accidents comprising e.g. industry specific subdivisions of the "Material agent" and "Working process" variables. These data were made available for research purposes upon anonymization of personal information and under an agreement abiding to the General Data Protection Regulation of the EU.

Articles [I] and [III] are based on analysis of occupational accident claims statistics of farmers and commercial fishers. In [III], also the complete occupational accidence insurance history data of the commercial fisher population was available, so a statistical assessment of population level risk factors was carried out.

In [I] and [III], frequencies and shares of study population and accident related variables were assessed by calculating one way and tabulated frequencies. In [III], binary generalized mixed model regression analysis was used to assess population level estimates for associations (i.e. odds ratio estimates) of injury predictors to the occurrence of occupational injuries among Finnish commercial fishers.

Variance analysis and Tukey's Honest Significant Difference (HSD) test were used to assess significance of differences between scorings of the positive influence of safety measures in [IV].

5.   Results

The results of this thesis, beyond the composed list of occupational safety clusters presented under "Materials and methods" in Subchapter 4.2, comprise 1) safety determinants derived from occupational accident claims records (Subchapter 5.1), 2) safety determinants derived from user centered surveys concerning effectivity of safety risk treatment (Subchapter 5.2), and 3) an assessment of the combined contributions of 1) and 2) to the knowledge of determinants relevant to occupational safety management (Subchapter 5.3).

5.1. Determinants of occupational accidents

Article I focused on assessing risks introduced by confined animal production environments, especially floor structures. Close to half (42% or 46634) of all compensated agricultural injuries in Finland during 1992–2002 occurred in animal production (dairy, beef, and swine). Out of these, 14% or 6414 were slip, trip or fall (STF) injuries caused by a floor structure such as a door sill, ramp, or manure gutter (ESAW material agent codes 1.00 and 2.01). These injuries happened during animal production related (cows or swine) activities (ESAW working process code 33).

Compared with women, men had a significantly smaller risk for STF injuries (rate ratio of 0.63; 95% confidence interval 0.61–0.67) in the respective activities in all production types. In bovine production, milking (including preparations), moving feed, and animal transport and care had the highest numbers of injuries. In swine production, removal of manure, feeding, and moving animals were the most frequent activities at injury [I].

Slips were clearly more common (77% of the STF injury burden) than trips (7%). Over half of the STF injuries involved physical strain, such as pushing, pulling, or lifting a load [I]. The presence of a contaminant or structure was frequently (57% and 40%, respectively) reported in combination with slips (Figure 15). Trips were reported to occur due to structures (68%) or obstacles (22%). Water, manure, and feed were typical contaminants, while common structures causing trips included manure gutters and grates (Figure 15).
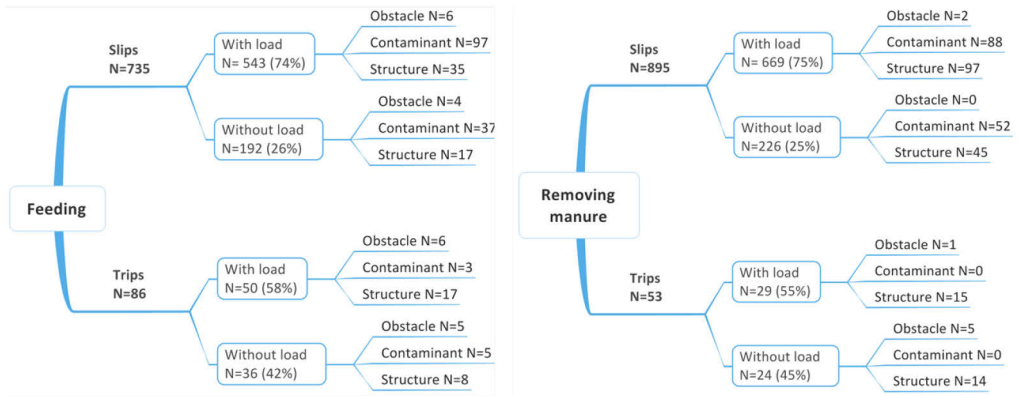
Figure 15. Contributing factors to STF injuries during feeding and removing manure [I].

Table 5. Structures and contaminants contributing to STF injuries in animal confinements [I].

Structure	Slips	Trips	Contaminant	Slips	Trips
Gutter	x	x	Forage, feed[a]	x	x
Curb	x	x	Manure, urine	x	x
Higher level	x	x	Moisture[b]	x	
Grate	x	x	Detergent	x	
Hose	x		Ice	x	
Sill	x		Snow	x	
Surface	x		Dust	x	
Stairs	x		Hay		x
Bunk	x		Afterbirth	x	
Ramp	x				
Door	x				
Step		x			
Stanchion		x			
Fence	x	x			
Doorstep		x			
Plank	x				

[a] Dry, moist, or frozen feed or forage; flour, grain, pellets, potatoes, etc.
[b] E.g. splashed from cow watering cups.

Article III focused on assessing predictors of occupational injuries and diseases in the Finnish commercial fisher population. The effects of membership to a voluntary based occupational health service program as well as additional cohort level predictors to injuries were examined. The additional cohort-level predictors that were available in the insurance data were gender, mother tongue, home region of the insured (corre-

sponding to the fishing area variable), age, income from fishing, and experience in fishing (estimated using the accumulated insurance period up to the accident).

The estimated odds ratios of both single predictors and for the predictors that remained significant in the binary regression model comprising all predictors (parsimonious model) are presented in Table 6.

Participation to the voluntary OH services was low (13.8%) among the studied fisher population [III]. Despite being included to the service package, only 62 out of 261 (or 23.8%) enrolled fishers had a workplace safety check done by the OH service provider. When corrected for effects of age, gender, mother tongue, fishing area, income level, and professional career length, the effect of participation in OH services were not statistically significant in the multivariate model.

Out of demographic factors, male gender, Swedish mother tongue (vs. Finnish), and higher income from fishing were statistically significant predictors of occupational injuries [III]. Age and length of career, i.e. experience, remained non-significant. The fishing area, representing both a contrast of coastal with lake environments, and possibly differing fishing methods and vessel types between these areas, was not significantly associated with injuries.

Table 6. Estimated odds of selected predictors for injury and disease claims made by fishers [III].

Predictor	Predictor category	Person insu-rance years	Number of claims	Single predictors			Parsimonious regression model		
				Estimated Odds Ratio	95% CI Lower limit	95% CI Upper limit	Estimated Odds Ratio	95% CI Lower limit	95% CI Upper limit
OH services membership	Member	2203	97	1.02	0.73	1.43			
	Non-member	17103	756	Reference					
Gender	Male	16641	793	2.33	1.57	3.45	2.02	1.37	2.99
	Female	2665	60	Reference			Reference		
Mother tongue	Finnish	12403	646	1.85	1.43	2.39	1.98	1.53	2.55
	Swedish	6903	207	Reference			Reference		
Fishing area	Coastal	14529	628	0.89	0.68	1.15			
	Inland	4777	225	Reference					
Age [years]	18–30	1001	52	Reference					
	31–40	3219	177	1.22	0.76	1.96			
	41–50	5989	279	0.98	0.61	1.55			
	51–60	7046	287	0.80	0.50	1.26			
	61–	2051	58	0.60	0.35	1.02			
Fishing Income [EUR]	over 15000	4856	344	3.56	2.50	5.06	3.53	2.48	5.02
	10001–15000	4882	223	2.25	1.57	3.24	2.33	1.62	3.33
	6001–10000	5121	283	1.68	1.16	2.43	1.71	1.18	2.47
	under 6001	4447	103	Reference			Reference		
Experience [years]	0–5	3426	143	Reference					
	6–10	2719	128	1.15	0.86	1.53			
	11–15	2852	144	1.22	0.90	1.64			
	16–20	2908	136	1.05	0.76	1.46			
	21–30	5482	234	0.93	0.69	1.25			
	31–	1919	68	0.81	0.40	0.94			

A summary of the safety determinants derived from the studies using accident insurance claims statistics [I, III] along with indication of the original source article is presented in Table 7.

Table 7. Summary of safety determinants derived from accident insurance claims statistics in the original articles [I] and [III].

Determinant cluster (defined in Subchapter 4.2)	Determinants derived from accident claims records	Article
Physical environment	Fixed structures: floors, gutters, door sills	I
	Loose obstacles and contaminants	I
	Geographic location	III
Organization and management	– (none detected)	–
Individual	Gender	III
	Mother tongue	III
	Age	III
	Income level	III
	Career length	III
Task	Milking and milking preparations	I
	Removing manure	I
	Bedding	I
	Moving feed and feeding	I
	Animal transport and care	I
	Carrying loads	I
Tools and technologies	–	–
External	–	–
Performance	OH services membership	III
	Workplace audits	III
Intervention mechanisms	–	–
Intervention drivers and barriers	–	–

5.2. Determinants of success of safety interventions

Article II focused on identifying barriers and enabling factors (a.k.a. drivers) that affect adoption and implementation of safety information on Finnish agricultural farms. To summarize these, the barrier and enabling factor constructs in Table 8 were created.

Table 8. Constructs of derived barriers and enabling factors from the farmer survey [II].

Barrier constructs	Enabling factor (driver) constructs
Personal inclinations	Power of examples
Limited resources	Ease of application of intervention
Evolution of farm environment	Enforcement

Personal inclinations, such as habits and attitudes, affect the immediate risk of injury. They are also likely to preserve existing hazards on the farm, because of their conservative nature. If established working habits were transferred to new environments (e.g. new, safer machinery and buildings), they can undermine potential gains of new investments in safety.

Rushing, long working hours, and lack of safety knowledge affect the inclination to actively identify hazards in the working environment and working habits. On the other hand, risks were ignored or downplayed when playfulness and competitiveness were a part of the work. Also, vanity was mentioned as an explanation for not acting safely.

Acting upon acquired safety and risk management knowledge or becoming aware of compromised safety requires both physical and human assets that may not be readily available at the time. Limited resources, in terms of e.g. raw material, tools as well as skills and time, affect hazard mitigating actions. This had resulted in deferring fixes, but also in making quick temporary fixes – which then had become permanent – with questionable safety. Individuals had ignored and neglected known hazards, and a certain level of risk was traded for perceived efficiency of work.

From a safety performance point of view, processes, tasks, and the farm environment were not always planned with safety as a priority. The working environment and ways of working on a farm are a result of decades of evolution, including investments in buildings and machinery, renovations, expansions, and even changes in production type. Structures and machinery become technically obsolete, but still form a part of the working environment. In some cases, they also had become functionally incompatible, leading to altered uses and workarounds that compromise safety.

Coping with gradual technical and functional deterioration of production assets requires resources and are thus subject to economic considerations. Decisions concerning investments in new and safer machinery and buildings were weighed against future plans and outlook of the farm.

The impulses to make work and the working conditions safer originated from positive or negative examples, experiences, and remarks made by peers, formal or informal authorities as well as family members and other close people. Close calls are were also mentioned to be impulses that not only make the hazard and potential consequences tangible, but also direct focus to specific targets that needed acute safety actions.

Other forms of observed experiential learning were mental training and personal activities (hobbies) that created preparedness for hazard identification, mitigation and accident prevention. Participation to voluntary firefighting was mentioned as an example of such activity that creates an "eye" for fire safety risks and their mitigation. Mental training included discussions, where scenarios and actions under normal and exceptional (involving an accident) conditions are envisioned.

Ease of application of a safety enhancing measure made its implementation more probable. Easiness referred to the requirements of physical resources and skills, but also execution time and timing in relation to e.g. production cycle and evolution of the farm.

Adoption of safety measures was boosted, if work comfort and efficiency benefitted from the same measure.

Rescue plans and fire detection systems are mandatory for new animal confinement buildings and were mentioned as safety drivers. Mandating these actions contributed to taking safety into consideration in the planning phase of working environments and processes. Safety enforcement also referred to inspections to control compliance or to ensure safety of e.g. electrical installations and heating systems.

Article IV addressed commercial fishers' views on the effect of safety regulations and other safety measures in five Nordic countries. The main aim of the study was to find out how the fishers score 13 common, pre-selected safety measures according to their experienced positive influence on safety. A scale of 1 to 10 was used for scoring. "1" denoted little or no influence and "10" great influence. If the safety measure was not relevant to the participant, a score of "0" was recorded.

The results of phone or contact interviews with a total of 47 experienced fishers yielded a tentative country specific as well as a common scoring across countries (Table 9). It also enabled a comparison and contemplation of similarities and differences in rankings between countries [IV].
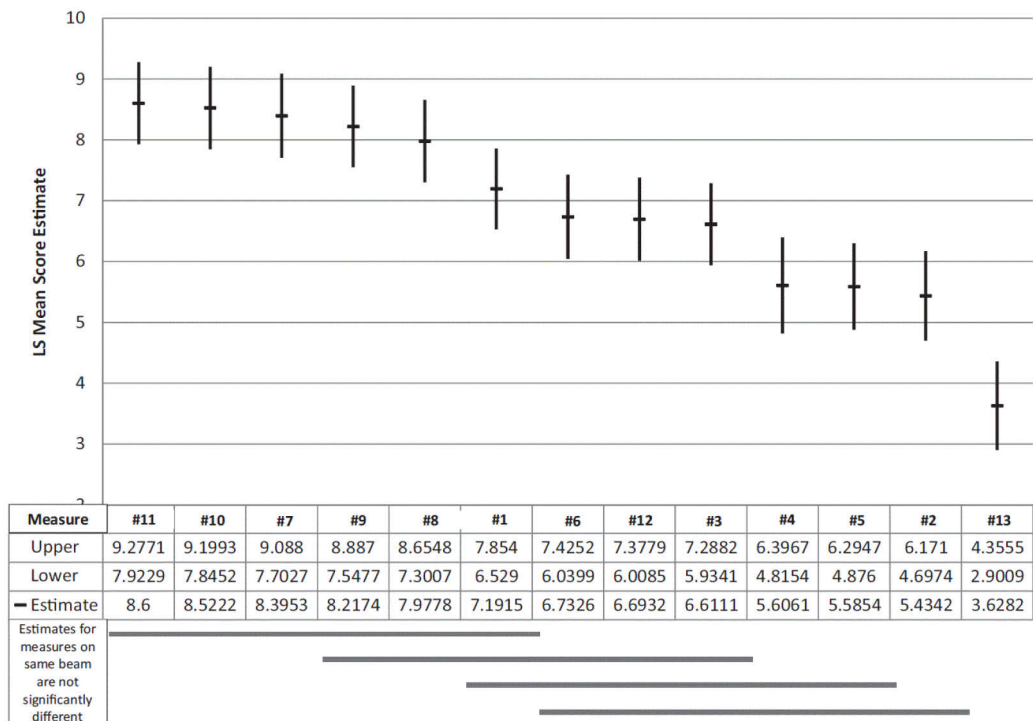
Table 9. Mean scores and SD (standard deviation) of the safety measures as assessed by Finnish fishers and fishers from the five Nordic countries [IV].

Safety measure	Finnish mean score (S.D)	All countries mean score (S.D.)
#1 Safety training in fisheries	4.9 (2.0)	7.2 (1.5)
#2 Other education in relation to fisheries and safety	4.4 (2.5)	4.5 (1.5)
#3 Rules, auditing and controls by authorities on safety and accident prevention in fisheries	4.0 (3.4)	6.5 (1.5)
#4 Guidelines and information from authorities on safety and accident prevention in fisheries	n/a *)	4.8 (1.7)
#5 Investigation and recommendations from authorities, e.g. Maritime Investigation Board	5.3 (3.1)	5.2 (1.6)
#6 Use of on-board workplace assessments	6.1 (3.5)	5.5 (1.4)
#7 Design and physical layout of vessel	6.7 (4.1)	8.3 (1.0)
#8 Technical aids on board to reduce workload, e.g. lifting gear	6.9 (3.3)	7.7 (0.8)
#9 Organization of work on board e.g. delegation of tasks, knowledge of what to do and who does what	8.4 (1.4)	8.2 (0.8)
#10 Safety equipment for fishers and vessel	8.3 (1.5)	8.6 (0.9)
#11 Safety culture on board	8.9 (1.1)	8.6 (0.4)
#12 Advice, help and support from consultants	8.1 (0.9)	6.2 (2.1)
#13 Advice and help from others; e.g. trade unions and organizations	4.7 (3.3)	3.0 (1.8)

*) n/a: Not applicable for Finland, no such authority.

The ranking of all 13 measures is tentative, since differences in the mean estimates of most pairwise comparisons were not statistically significant [IV]. Safety culture (#11), safety equipment (#10), the design and physical layout of the vessel (#7), organization of work on board (#9), and technical aids to reduce workload (#8) ranked highest with a mean estimate close to or greater than 8 ("good influence") (Figure 16). A common denominator for these five highest scoring measures is that they are an integral part of the everyday fishing work and concretely promote safety, efficiency and continuity of the profession.

In contrast with this, other education in relation to fisheries and safety (#2), investigations and recommendations from the authorities (#5), and guidelines and information from the authorities on safety and accident prevention in fisheries (#4) scored lowest with estimated means below 6 ("mediocre influence") [IV]. Advice and help from trade unions and organizations (#13) scored lowest ("insignificant influence"). Possible reasons for the low estimated mean scores are rare safety related training for experienced fishers, the apparent role of trade organizations as primarily political actors, missing or poor public safety information, and dislike of safety regulations ordered by authorities.

Measure	#11	#10	#7	#9	#8	#1	#6	#12	#3	#4	#5	#2	#13
Upper	9.2771	9.1993	9.088	8.887	8.6548	7.854	7.4252	7.3779	7.2882	6.3967	6.2947	6.171	4.3555
Lower	7.9229	7.8452	7.7027	7.5477	7.3007	6.529	6.0399	6.0085	5.9341	4.8154	4.876	4.6974	2.9009
▬ Estimate	8.6	8.5222	8.3953	8.2174	7.9778	7.1915	6.7326	6.6932	6.6111	5.6061	5.5854	5.4342	3.6282

Estimates for measures on same beam are not significantly different

Figure 16. Tentative ranking of safety measures #1-#13 (Table 9) across countries by least square mean estimate [IV]. Differences of mean scores between measures that share the same beam (lower part of the figure) are not statistically significant.

Statistically significant differences in scorings of measures, both in-country and be-tween countries, were detected. The range and standard deviation of scorings between countries was the smallest for "Safety culture on board" (#11), indicating common agreement on the highest ranked effect of safety culture. Other fairly coherent evalua-tions were given for the rest of the across country top five high ranking measures (#7–#10). Measures #2 ("Other education in relation to fisheries and safety"), #5 ("Investiga-tion and recommendations from the authorities e.g. Maritime Investigation Board"), and #12 ("Advice, help and support from consultants") had the widest range and high SD between countries, indicating differences between the country mean scorings. Statisti-cally significant pairwise differences between countries were detected for measures #1, #3, #5, #9, #10, #12, and #13.

A summary of the safety determinants derived from user-oriented surveys aimed at assessing aspects of efficacy of occupational safety risk treatment in articles II and IV, with reference indication to the original source article, is presented in Table 10. Essen-tially similar determinants have been combined and shortened from the expressions in the original articles to condense the table.

Table 10. Summary of safety determinants affecting efficacy of safety risk treatment, derived from the user-oriented surveys in [II] and [IV].

Determinant cluster (defined in Subchapter 4.2)	Determinants derived from user-oriented surveys	Article
Physical environment	Evolution of farm environment	II
	Aging and deterioration of materials and structures	II
	Partial deliveries of equipment	II
	Inadequate storage facilities	II
	Storing materials in unplanned, unsuitable locations	II
	Alternate uses of built spaces create hazards	II
	"Invisible" physical, chemical and electric hazards	II
	Temporary structures and quick (safety) fixes	II
	Design and physical layout of vessel	IV
	Technical aids on board to reduce workload	IV
Organization and man-agement	Evolution in production over years	II
	Future of production: phasing out or growing business?	II
	Organization of work on board	IV
	Safety culture on board	IV
Individual	Attitudes, habits and behavior	II
	Ignoring and neglecting known hazards and risks	II
	Playfulness and competition	II
	Skills and knowledge	II
	Lack of time, long working hours, rushing	II
	Vanity	II
	Respect towards views of close people	II
	Aptitude for change and development	II
	Transfer of old habits to new environments	II

Task	– (none detected)	–
Tools and technologies	Lack or limited availability of adequate tools and supplies	II
	Deficiencies in tools and machines that affect workflow	II
	Functional incompatibility of tools, machines, and buildings	II
External	Remarks, advice and requests by authorities and peers	II
	Investigation and recommendations from authorities	IV
	Guidelines and information from authorities	IV
	Safety rules, auditing and controls by authorities	IV
	On-board workplace assessments	IV
	Advice and help from trade organizations and consultants	IV
Performance	Trading risk for perceived efficiency of work	II
	Rethinking processes to eliminate hazards	II
	Weak safety planning of tasks, tools and environment	II
	Accumulation of risks allowed or not recognized	II
	Cost cutting and economic optimization	II
	Safety equipment for fishers and vessel	IV
Intervention mechanisms	Personal interest, learning from other activities and hobbies	II
	Power of examples	II
	Subjective experiences and learning from other' experiences	II
Intervention drivers	Peer example and topical interaction with peers	II
	Experiences of injuries or close calls	II
	External impulses	II
	Ease of application of safety measure	II
	Contribution to efficiency or convenience of work	II
	No-cost, ready-to-apply safety solutions	II
Intervention barriers	Peer pressure	II
	Limited resources: time, skills, materials, tools	II
	Incremental accumulation of risks complicates risk detection	II
	Availability of supplies for repair and maintenance	II

5.3. Contribution of case studies to safety determinant clusters

The contribution of the underlying studies [I-IV] to individual occupational safety determinant clusters (Subchapter 4.2) is shown in Table 11. The contribution of Article [I], with a specific orientation to accidents caused by animal confinement floor structures, comprised determinants describing physical environment factors as well as tasks associated with accidents. In Article [III], determinants describing individual demographics, safety performance and geographic working location (specifying aspects of the physical environment) of the insured commercial fishers could be assessed. Both Articles [I] and [III] were based on accident claims records with a limited set of variables available for analysis.

Table 11. Overview of the distribution of derived determinants by determinant clusters in the original articles I–IV.

Original Article	I	III	II	IV
Topic	STF type injuries in animal confinements	Predictors of fisher injuries	Intervention barriers and drivers in agriculture	Importance of interventions in fisheries
Material source	Accident records	Accident records and insurance history data	Interviews, self-documentation	Interviews
Approach type	Retrospective	Retrospective	Prospective	Retrospective and Prospective
Physical environment	X	X	X	X
Organization and management	–	–	X	X
Individual	–	X	X	–
Task	X	–	–	–
Tools and technologies	–	–	X	–
External	–	–	X	X
Performance	–	X	X	X
Intervention mechanisms	–	–	X	–
Intervention drivers and barriers	–	–	X	–

X: determinants belonging to this cluster were detected
– : determinants belonging to this cluster were not detected

Article II focused on intervention barriers and drivers and contributed occupational safety related determinants to all but one determinant cluster. The spectrum of derived determinants is wide due to the user-involving research method that facilitated collaborative elaboration of safety related factors on agricultural farms. The safety measures ranked by commercial fishers in Article [IV] comprised predominantly external safety measures (e.g. safety training, official inspections, advice and help from consultants), but also measures related to safety performance, safety of the physical environment, and the contribution of organizational factors were included.

Combined, the case articles contributed to all occupational safety determinant clusters. They provided examples and insight to both contextual determinants of occupational accidents as well as to intervention specific determinants in the work system that affect the success of safety treatment.

6. Discussion

The main aim of occupational safety and health (OSH) related research as well as intervention research is to produce information that supports mitigation of accident risks and promotes OSH. The essential question then is: How and under which preconditions do findings of these research efforts contribute to promotion of occupational safety and health? In the first Subchapter (6.1), the information content derived from the underlying studies [I – IV] is compared with previous studies, using the occupational safety determinant clusters as the discussion framework. The second Subchapter (6.2) comprises contemplation on the contribution of the determinants compiled in this thesis with respect to their contribution to safety management. Implications of the original information sources and methods on detection of determinants are also discussed. In the third Subchapter (6.3), main strengths and limitations of this thesis are assessed.

6.1. Occupational safety determinants in agriculture and commercial fishing

The individual determinant clusters comprise coherent categories of factors describing the context and human factors in the work system where accidents occur and are mitigated by occupational safety interventions. In the following paragraphs, the determinants derived in Articles [I – IV] are discussed with respect to previous studies. The discussion also contributes to describing the information content of each cluster in the domains of agriculture and commercial fishing.

Physical environment
Slips, trips and falls with a recorded cause related to floor structures represented 11% to 15% of all injuries during the years 1992–2002 in Finnish agriculture [I]. The significance of this type of injuries has been recognized in the agricultural OSH domain (Rautiainen et al. 2004, Mattila et al. 2008) as well as in commercial fishing (Kaustell et al. 2016), and in other domains (Chang et al. 2016). Fishers evaluated the contribution of design and physical layout of the fishing vessel to safety to be significant safety factors [IV].

Besides the design and layout of the environment, also other physical aspects of the work, like temperature and humidity, and properties of the footwear with respect to flooring materials and work must be considered (Grönqvist et al. 2001, Lehane & Stubbs 2005, Shu et al. 2005). In [I], these comprised contaminants, obstacles, and specific fixed structures like manure gutters, curbs, and ramps. Carrying, pushing or pulling a load during the work was an additional hazard factor detected. Safety related determinants of fishing included the fishing area, which also has implications on the physical environment [III].

Evolution of production over decades affects the physical work context. Typical consequences are gradual deterioration of built structures and old machinery as well as them being functionally or physically incompatible with the current production. This

development leads to temporary quick fixes, alternated uses of built spaces, and added need for maintenance and repair [II]. Maintenance, repair, and construction work are among the most hazardous tasks in agriculture (Rasmussen et al. 2000, Rissanen and Taattola 2003).

Both the statistical and the human centered approach yielded information of the physical environment that is a central causal safety determinant and that has had center focus in the accident research tradition. The information in the statistical sources comprised mostly substantives naming parts of the physical environment, e.g. door sills [II], fishing area [IV], and surface contaminants [II]. In contrast with this, the user-centered sources expressed safety related functions and even causalities related to the physical environment, e.g. aging and deterioration of materials and structures [II], functional incompatibility of the physical environment and work [II], and technical aids on board to reduce workload [IV]. The difference in information content is evident, but both data contributed to safety management.

Chang et al. (2016) concluded that due to "the multi-factorial nature" of the etiology of slip, trip and fall injuries, a systems approach is essential to promote safety to prevent this type of injuries. According to the performance approach (PA), the design of buildings (or built environments) should be based on performance requirements by users and other stakeholders rather than those set by construction and technical solutions (Spekkink 2005). For built environments, PA could thus provide a framework for making safety aware decisions concerning both building and work design [II]. Use of PA would incorporate consideration of a large set of safety related determinants, reflected in the international standard "Framework for specifying performance in buildings" (ISO 2016). Some of these include stability, guard railing, surface properties, and adaptation for changed usage.

Organization and management

Organization of work and management decisions were assessed to affect work safety on board of fishing vessels [IV]. These decisions manifest themselves on the workplace as e.g. ability to delegate, common knowledge of responsibilities, and task sharing. In the same study, also safety culture on board was assessed to have significant positive influence on injury prevention in fishing. Repeated, mandatory safety training may keep safety on the agenda of fishers better than one-time participation to a safety course during vocational training years ago. When no safety training or certification is needed for fishing, it is up to personal interest and involvement to keep safety skills and equipment up to date. The interplay of management and safety climate, along with its implication on occupational safety was described by Zohar (2014), and a significant association of poor management related indicators, such as delays in work and stress, with occupational injuries was also observed by Suutarinen (2004).

The organization structure is low on Finnish farms and commercial fisheries. It comprises mostly self-employed entrepreneurs with varying amounts of family workforce (Salmi 2005, OSF 2019b). The experienced positive effect of the "Organization of work

on board" safety measure [IV] may link to safety performance via formalized safety treatment in a multi-actor work community with diversified management and worker profiles (like on a larger fishing vessel with a salaried fishing crew). The indication that also Finnish fishers, working on their own or in pairs, rating this safety measure high stresses also the importance of organizing one's own work with safety in mind. This effect of the fishers integrating risk management into their daily work was described by Thorvaldsen (2013).

Decisions concerning future of the business also have safety implications. Phasing out vs. growing the enterprise affects the inclination to invest in safety [II]. Possible mechanisms at play behind these effects were described by Hollnagel et al. (2015). They argue that if investments in safety are considered only as costs with no productive effect, and times are hard economically – as they would be in phasing out situations – these investments are not made. On the other hand, if the investment has both safety and productivity enhancing effects – as could be expected by growing operations – the decision to invest in safety is made more easily. This intervention driver was observed in Article [II]. The variation of aptitude for investments with business and career phase of the farmer was also found by Lien et al. (2006) and Hyvärinen (2016).

Human related (individual) determinants

Accident record-based risk assessment typically yields demographic (non-behavioral) human factors of victims, such as age, gender, nationality, mother tongue, income level, and career length ([I], [III], Jadhav et al. 2016, Kaustell et al. 2016, Kaustell et al. 2019). These are used to profile and propose intervention target groups with elevated risk levels. Basic demographic factors like age, gender, and tenure are also used as control or confounding variables when determining correlations between individual safety determinants and safety outcomes (DeJoy et al. 2003, Jadhav et al. 2015). In the EU, the ESAW coding of accident data (Eurostat European Commission 2013) provides the statutory background and a list of variables for collection of these data in conjunction with occupational accidents.

Behavior, attitudes, and skills of individuals were found to be connected to safety [II]. The association of the farmers' habits, specifically poor safety habits, to occupational accidents was reported by Glasscock et al. (2006). Also, other safety affecting habits and behavioral models exist, e.g. piling up hay bales as high as possible without a specific need to do so, possibly as a form of playful competition [II]. Among commercial fishers, Davis (2012) found that undervaluing risks was connected to individual determinants such as non-compliance with safety regulations, fishing family background, and risk-loving tendencies. Human behaviors and individual characteristics, along with their antecedents, may also contribute positively to occupational safety.

The effect of cultural background was hypothesized in [III] where fishers who speak Swedish as their mother tongue had a significantly lower risk for occupational injuries than the Finnish speaking fishers. The same effect has been found among Finnish farmers by Taattola et al. (2012) and Karttunen and Rautiainen (2013). Other cultural back-

ground related effects, like diverse safety attitudes and other cultural differences affecting safety behavior among seasonal foreign workers, were observed by Rautiainen et al. (2012).

Lack of knowledge and skills to identify risks and risk buildup as well as knowledge on how to mitigate risks constitute another set of safety related individual traits found in the underlying study [II]. These risk factors were also identified by Colémont and Van den Broucke (2008), Lovelock and Cryer (2009), and Irwin and Poots (2015).

Consideration of the factors belonging to the "Individual" safety determinant cluster is a challenging, but crucial task in both risk assessment and risk treatment (Colémont and Van den Broucke 2006, Anyaegbunam 2007). The challenge of utilizing these determinants in safety promotion is related to the intermediating (the "meso level" discussed in Subchapter 2.4) role of the individual (Carayon 2009): The behavior and acts of the individual depend on both the work context as well as physical and cognitive traits of the person in question. Information of these background factors is sparse or non-existent in accident statistics, but possible to acquire with surveys. A more extensive application use of human factors research methodologies based on models of human behavior would probably contribute to the understanding of accident causality and mitigation of occupational safety risks.

Task related determinants

Milking and animal care related tasks and tasks associated with carrying loads [I] were found to be associated with injuries. The association of tasks to occupational injuries and diseases in agriculture and fishing has been extensively assessed (e.g. Marshall et al. 2004, Mattila et al. 2008, Kallioniemi et al. 2011, Thorvaldsen 2013, Karttunen 2014, Jadhav et al. 2016). It has been used to point out hazardous working phases. Repetitive manual phases of work were found to be associated with occupational diseases of commercial fishers by Kaustell et al. (2016).

Tasks related to care and handling of animals on livestock farms are among the most dangerous in agriculture (Mela 2019a). Specific animal handling strategies involving planned behavior patterns of the animal handler can potentially reduce the risk of injury (Kallioniemi et al. 2011). This example points out the necessity to consider interactions between the Task cluster and the Individual cluster. Mental safety implications of individual tasks in agriculture and fishing have been studied in lesser extent and were not detected in the underlying studies [I–IV] of this thesis, which can partially be due to their original scopes and methods. The effects of use of advanced farm technology was studied by Lunner Kolstrup et al. (2018) who found that the negative effects i.e. mental strain of new technology were mainly based on bad design and on unreliability of the used equipment and services.

Tools and technologies

References to safety implications of tools and technologies were made regarding production methods involving carrying of loads [I]. Additionally, technical failures or defi-

ciencies of production equipment and lack of necessary or adequate tools and supplies to accomplish safe maintenance work and constructions [II] were detected. A case study reported in [II] revealed that a design flaw in a motorized loader used during feeding inside a dairy barn was a causal factor to a fire that almost cost the farmer's life.

In accident statistics that abide by the ESAW methodology and coding (Eurostat European Commission 2013), tools and technologies related information is mainly documented under the variables "Specific physical activity" and "Material agent". Some 38% of compensated injury claims of Finnish farmers were caused (according to the Material agent classification) by tools and machinery (Mela 2019a). Information on the material agent involved in accidents can be found in accident statistics. Still, it may remain unclear, if ergonomy, usability or other design aspects of the tool or used technology actually contributed to the accident (Kogler et al. 2015).

External determinants

Remarks, advice and requests by authorities and peer farmers were mentioned to have positively influenced safety on farms by leading to corrective actions [II]. A similar assessment was made among the commercial fishers regarding advice, help and support from consultants as well as rules, auditing and controls by fisheries safety authorities [IV]. In the same study, advice and help from e.g. trade unions and organizations as well as investigations and recommendations from the authorities, were assessed to have only mediocre or insignificant contribution to safety in fisheries. Fisheries management regulations, such as fishing quota systems, can influence work planning and safety behavior of fishers (Pfeiffer and Graz 2016). The significance of interaction with peers to farm safety behavior has also been recognized in earlier studies (Stave et al. 2007, Kawakami et al. 2008, Brennan 2015).

The implications of non-mandating measures (such as advice, investigations, and recommendations) by formal authorities and organizations may vary with applicability of the suggested measures in the work context and perceived prominence of the respective actor (Lindøe 2007). Mandatory safety rules, such as a ban on a toxic pesticide and enforcement of use of roll-over protection system (ROPS) in tractors without a safety cabin, have been found effective in promoting positive safety and health outcomes (Rautiainen et al. 2008).

Safety and organizational performance

Indications of risk increasing economic optimization (trading safety for economy) as well as safety compromising or promoting acts were found in the underlying studies [II–IV]. Risk was traded for perceived work or economic efficiency and such behaviors were also found among farmers by Glasscock et al. (2006), Antão et al. (2008), Håvold (2010), and Hagel et al. (2013). Hale (2003) and Carayon et al. (2015) argued that safety or safety management may conflict with other organizational goals, i.e. organizational performance.

The effects of safety considerations during planning of investments and work design were other safety performance related factors found in [II]. These have also been discussed by Antão (2008) and Irwin and Poots (2017). Small size of enterprises – typical to Finnish agriculture and fisheries – as well as rarity of serious accidents lead to omitting effective safety management according to Hale (2003).

The role of participation to occupational health (OH) services was discussed in the underlying studies [III] and [IV]. The safety effect of participation to OH services among Finnish fishers was found close to indifferent in [III]. A corresponding indifferent or even negative effect of OH services enrollment to injury risk among Finnish farms was reported by Karttunen (2014). In contrast to the Finnish results, the results in [IV] show that Danish fishers ranked their corresponding national OH service to have great effect on occupational safety on board. Some of the reasons for this discrepancy may be attributed to low participation rates to the voluntary OH services among Finnish farmers (38%, Leppälä 2016) and fishers (13.8%, [III]), or flaws in the intervention theory or implementation (Kristensen 2005, Pedersen et al. 2012).

Intervention mechanisms

The intervention mechanisms identified in the underlying user-centered studies were related to personal motivation for safety ("safety attitude") [II, IV], subjective and observed experiences of safety related incidences ("power of examples") [II], and social mechanisms, like a common sense of safety challenges and their solutions [IV]. This social mechanism was also observed by Thorvaldsen (2013) among fishers.

Generally, the intervention mechanisms aim at pointing to and explaining the effect of mental processes that cause interventions to work or to not work. The approach is quite young, and a solid theory of intervention mechanics has not yet been established (Micheli et al. 2018). Determinants in the "Individual" safety determinant cluster, based on the antecedents of human behavior, could at least to some point resonate with determinants in the "Intervention mechanism" cluster, especially in contexts, where potential victims of occupational accidents at the same time are responsible for safety management at the workplace.

Intervention drivers and barriers

Interaction with peers, both by observing examples and discussing safety promotion, were found to be drivers of safety enhancements made on Finnish farms [II]. The positive effect of peer involvement was also found by Rautiainen et al. (2012) who studied factors affecting occupational safety and health among foreign farm workers. Success of social marketing of agricultural safety and health, involving peer farmers as messengers was reported by Anyaegbunam (2007). The supporting effect of trusted sources knowledgeable in production practices was underlined by Chapman et al. (2011).

Ease of implementation and contribution to efficiency of work are safety solutions related drivers [II, IV]. These aspects stress the importance of usability and user centered design of any safety measures involving engineering, education, economy, or en-

forcement interventions. It relates also to the experienced relevance of safety infor-mation provided to target groups [III]. Ease of implementation also resonates with the farmers' preference for "not too laborious" management systems (Leppälä 2016), and contribution to work efficiency certainly is welcomed by farmers and fishers who work under high production pressure (Lunner Kolstrup et al. 2013).

The safety and health promoting impact of close calls happening to the individual or their close acquaintance found in [II] was earlier reported to affect safety behavior and "respect for risks" (Geller 2002, Lovelock and Cryer 2009,). On the other hand, Hasle et al. (2009) noticed that experienced accidents on the workplace do not necessarily lead to better safety performance.

The effect of enforcement was brought up in [II] regarding fire safety of buildings. Mandatory rescue plans and fixed smoke detection systems in dairy cow buildings as well as inspections of electrical installations every 15 years (every 10 years as of January 1, 2017) were mentioned as safety drivers. Regular workplace inspections can ensure the basic safety level, but also act as learning events, and keep safety management on the agenda. All these measures are subject to inspections at deployment of a new agri-cultural production building. The building owner must order the follow-up electrical installation inspection. This obligation had obviously not been fulfilled nor controlled on some of the visited farms in [II]. Some 50% of the fires in agricultural buildings are claimed to be caused by electrical installations (Nurmi et al. 2005).

Peer pressure was found to be a barrier of acting safely, even with knowledge of the apparent risk [II]. While interaction with other farmers was a potential driver, peer pres-sure originating from inside the work community and custom ways of working posed barriers to occupational safety. Possible explanations included hurrying and a feeling of inferiority in the social context. The effect of peer pressure relates to safety culture in the workplace (Håvold and Oltedal 2018).

Other barriers found in [II] included limited resources in terms of time, physical re-sources (supplies) skills and knowledge for making safety enhancements on the farm, and lack of adequate tools. These correspond to the list of barriers found by Cryer et al. (2009) who stressed that access to safety information is not a limiting factor to imple-mentation of interventions. Instead, lack of time, cost and access to practical infor-mation were the top three barriers.

The incremental evolution of the farm environment, e.g. gradual investments in building extensions, new machinery and changes in production may introduce gradually emerging hazards [II]. Functional incompatibility of tools, implements, machines, build-ings as well as working methods and processes can lead to altered, unsafe working prac-tices in the long run. This is due partial changes of the working environment without assessment of the safety implications of e.g. a new machine investment to the work system.

6.2. Contribution of occupational safety determinants to safety management

The occupational safety determinants extracted in this thesis are based on findings in the underlying studies [I–IV]. These studies represented various source data, research topics, aims and methodology. The source data of Articles [I] and [III] comprised administrative records of occupational accidents and diseases, whereas the data in Articles [II] and [IV] consisted of documentations of user (farmer and fisher) experiences. Assigning study results from differing sources to a common determinant cluster structure broadened the content of the determinant clusters and facilitated assessment of common background factors, typical causalities and implications on occupational safety risk management. The occupational safety determinants derived in this thesis study correspond well to the concepts and examples of determinants found in earlier studies (Subchapter 2.8, Table 2).

Determinants derived from accident statistics

The use of accident statistics facilitated characterization of injuries and victims as well as assessment of relative risk levels within the pool of included variables [I, III]. In combination with respective cohort level data, it was possible to assess population level risk factors [III]. The main reason for collection of administrative accident data used in studies [I] and [III] is to serve as documentation of injuries to be used during decisions in insurance matters. These data can be used to assess characteristics of the injured individuals, risk factors, causes, and consequently to point out intervention targets. However, analysis of this data includes only scarce implications and starting points on how accidents could be prevented (Rautiainen et al. 2009).

Intervention mechanisms comprising "cognitive and psychological states" that affect implementation of interventions (Micheli et al. 2018) are per definition not among the determinants documented in ESAW compliant accident data. Acknowledgement of macroergonomic factors, such as the physical, organizational and social context, is essential for safety management (Carayon 2009). Bondy et al. (2005) concluded that accident investigation methodology should lead to recording more information on human, organizational, and environmental factors.

Determinants derived from user-oriented studies

User centered approaches were applied in studies [II] and [IV]. The studies involving direct user input [II, IV] contributed, among others, to the determinant clusters "Organization and management" and "Intervention mechanisms" (Subchapter 5.3, Table 11) where there was no input from the accident statistics based studies ([I] and [III]).

The key idea leading to both projects was to understand the individuals' ways of thinking and reasoning around why some safety measures or interventions work for them while others do not. Apart from certain temporal context factors documented in accident reports, this kind of information cannot be found or deduced from accident

data sources. It is essential to identify intervention mechanisms as well as drivers and barriers to safety related behavior, because overseeing these during intervention design or implementation can lead both to program failures (wrong choice of intervention target or implementation) and theory failures (false assumptions on how intervention measures are transferred to safety effects) (Kristensen 2005).

Applicability of occupational safety determinant concept

Pillay (2015) concluded that there is a need for a theoretical framework that would integrate accident causation and safety management research. Multi-faceted and holistic approaches have been proposed for both the risk assessment (Schulte et al. 2012, Fennell 2017) and risk treatment (Lilley et al. 2009, Lovelock & Cryer 2009, Baumann et al. 2012) components of occupational safety and health management. Also factors that are not true points of intervention should be considered (Bondy et al. 2005). The concept of occupational safety determinants and the composed list of safety determinant clusters applied in this thesis study take steps towards finding common ways of thinking as well as common methods to assess, discuss, and utilize occupational safety risk assessment and risk treatment related determinants.

In this thesis study, multiple methods and approaches as well as two different industries (agriculture and fisheries) were used to derive occupational safety determinants and to compose a list of determinant clusters. According to Pillay (2015), interaction between multiple disciplines can facilitate new effective ways to mitigate occupational safety and health risks. While this study focused on injuries, the compiled list of occupational safety clusters can also be helpful in risk assessment and mitigation of occupational diseases. This claim is supported by the connections and interactions between health and safety discussed in Subchapter 2.1. The arguments behind the broad definition to the concept of determinants (Subchapter 2.9), regarding complex causality and the need to consider a broad set of both causation and intervention related contextual and human factors, also apply to occupational health.

Another argument for considering new approaches to assess determinants of OSH is the "What-You-Look-For-Is-What-You-Find or …-What-You-Fix" (WYLFIWYF) effect described by Lundberg et al. (2009). It means that, in safety risk assessment and accident analysis, the theory and methods always affect the finding of causal factors. Accident investigations can therefore not be without bias (Hollnagel and Macleod 2019). Using the list of safety determinant clusters does not completely enable avoiding this pitfall. When used for both safety risk assessment and design of prevention initiatives (as intended per definition in Subchapter 2.9), it still may broaden the scope of approaches and assist building links between accident and prevention contexts and human factors.

Hollnagel et al. (2015) took the idea one step further: with a rare phenomenon like accidents, it would be useful to also study why work usually proceeds safely: What are the determinants that facilitate safe work in 99% of the cases, and what variation among those determinants leads to safety failures? This approach resonates with the concept

of safety resilience and safety resilience engineering discussed by e.g. Hovden et al. (2010), Hollnagel et al. (2015), and Chen et al. (2017).

6.3. Strengths and limitations of thesis

Various source materials, methodological approaches, and underlying theoretical models used in this thesis study and the underlying case studies [I–IV] provided a rich set of data for analyzing occupational safety determinants. Study [I] provided additional information to be considered in safety aware design of the physical farm environment by combining coded data and data extracted from injury narratives from the accident insurance claims data. In study [II], the user-centered method of Cultural Probes was used as a new method to study intervention mechanisms, barriers and drivers. It yielded new insight as to how farmers experience hazards and safety enhancements. In [III] accident insurance claims data was combined to the complete insurance history data of the insured, self-employed fisher population over a history of 20 years. The method facilitated assessment of absolute risk levels in commercial fishing. The user-centered Nordic survey [IV] provided new insight to the fishers' views on "What works?" regarding safety measures in fisheries. The study also enabled assessment of possible background factors for the differences and similarities of the fishers' assessments between countries.

The use of both statistics and user-centered approaches made it possible to assess their strengths, weaknesses and differences with regard to their contribution to the knowledge of occupational safety determinants. The user-centered approaches could have applied the theories and models of human behavior to a greater extent to detect even more acknowledged antecedents of occupational safety incidents.

Various sources, theories, and approaches to collect information regarding safety risk management were used for detecting and assigning determinants to a composed list of safety determinant clusters. Results from both agriculture and fishery related sources as well as from other industries were used to reinforce the determinant approach and the composed list of safety determinant clusters this thesis. The list facilitates new considerations and development of data collection and safety management.

This thesis used case studies [I–IV] to reach its goals. The original aims, data, and methods used in these studies influenced what determinants could be detected. These background factors lead to the fact that this thesis study did not detect some important occupational safety determinants. E.g. economic incentives have been reported to promote safety performance (Champoux and Brun 2003), but were not among the extracted determinants of this study. Equally, the contributing effects of personal risk factors, such as chronic diseases, obesity, smoking, alcohol use, prescription drug use etc., to occupational safety risks (Shulte et al. 2012) did not emerge because of the case material used. All these relevant but missed factors could, however, be assigned to the compiled determinant cluster structure of this study.

The derived determinants originated from studies among farmer and fisher populations in Finland. Small scale, family-driven farming and fishing are common also e.g. in

the other Nordic countries which, from a socio-ecological point of view, enables application of the list of safety determinant clusters and respective determinants in corresponding contexts outside Finland. The determinant clusters are based on established models and representative research outside the scope of agriculture and fishery and should therefore be applicable also in other industries.

Assignment of individual determinants to determinant clusters (Subchapter 5.3, Table 11) is not unambiguous because of the multiple interrelations and chains of effect. As an example, a history of experienced negative safety outcomes (incidents, accidents, and injuries) can promote safety-oriented motivation and behavior of the individual involved. This effect was accordingly assigned to the "Intervention mechanism" cluster. According to Karttunen (2014), previous injuries are also associated with several occupational injury or disease risk factors. In that sense, injury history is also a demographic trait of an individual and could equally be assigned to the "Individual" cluster. Inference of the actual effect of detected single safety determinants (e.g. age, a specific tool, or weekday of the accident) to the chain of effects leading or contributing to the accident is always subject to ambiguity, regardless of the determinant source.

The accident insurance claims data used in studies [I] and [III] are subject to underreporting and misclassifications, and it is not possible to assess the effect of these error sources to the results of respective studies. The data used in analyses originated from the years 1992–2002 [I] and 1995–2015 [III]. With the growth of average herd size, introduction of automation as well as new housing types and herd management systems since those periods, it is possible that the relative shares of different accident types have changed. It is not likely that the work context in Finnish fisheries has changed as much as in agriculture. The effect of these source errors is limited, because the focus of this thesis study was not in detecting relative or absolute risk factors but rather to detect as many occupational safety determinants as possible.

The source material in the user-centered approaches [II] and [IV] may be subjectively or topically biased due to small study populations and cultural differences. The research method in study [II] included a validation round to minimize interpretation errors made by the research group.

7. Conclusions

Based on this thesis study, the following conclusions with regard to the study objectives and recommendations concerning future research and further development of occupational risk management related activities in Finnish agriculture and commercial fishing are made:

Conclusions with respect to study objectives

1. Composed list of occupational safety determinant clusters

    The concept of occupational safety determinants and the list of occupational safety determinant clusters composed and applied in this thesis facilitate and promote a holistic view on occupational safety risk management integrating aspects of both safety risk assessment and risk treatment. The approach also led to contemplations on how the determinants connect to each other.

2. Accident related safety determinants

    Occupational accident insurance claims records of Finnish farmers and commercial fishers provided a well-defined source for the evaluation of risk assessment related safety determinants. The use of accident statistics facilitated characterization of injuries and victims as well as assessment of relative risk levels within the pool of included variables. Accident statistics comprise, however, only a limited set of variables, and information on organizational and management related determinants as well as external factors potentially influencing the etiology of the accident was not available in accident claims records.

3. Work system related determinants that affect efficacy of occupational safety interventions

    The utilization of user centered, participatory approaches engaging persons from the actual target group into producing material for analysis, and for discussion and validation of the analysis results yielded a broad spectrum of occupational safety determinants. By designing surveys that facilitate assessment of the way of thinking and reasoning of the study subjects with regard to occupational safety topics, it is possible to gain information and derive determinants related to accident etiology and causation as well as mechanisms, barriers and drivers of occupational safety interventions.

4. Contribution of derived determinants to safety management

    Deriving determinants from studies on both accident insurance claims records and user centered surveys concerning efficacy of interventions complemented the information of occupational safety determinants. Multi-faceted approaches are needed to provide comprehensive information that is essential for formulation of effective interventions and safety risk management.

Recommendations

1. The determinant approach and clustering should be tested and applied in further work on safety and health risk assessment and prevention to validate, amend and reinforce them as useful tools in the domain of occupational safety and health.

2. Occupational accident data should be collected with more respect to the information needs of both risk assessment and successful risk treatment. This could be accomplished by ensuring uniform and complete collection of the data. Additional information on factors with a connection to the accident, such as a more detailed description of the context of work during the accident, would be beneficial.

3. OSH-related research should focus on identifying mechanisms as well as barriers and drivers to adoption of OSH interventions using user-oriented approaches that activate the subjects to self-reflection, expression and discussion of factors underlying hazards and accidents. The approaches should be based on theories and models of human behavior to facilitate systematic assessment and utilization of the results in accident prevention initiatives.

4. The efforts all interest groups (farmers/fishers, vocational education, extension services, social insurance companies, occupational health organizations, governing bodies, and research) should be coordinated to promote occupational safety and health. Topics of coordination should encompass follow-up and discussion of recent trends in occupational safety and health, knowledge needs regarding effective mitigation of OSH problems, and development of joint projects to reduce the burden of occupational accidents and health problems in agriculture and commercial fishing.

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