Tanja Risikko

SAFETY, HEALTH AND PRODUCTIVITY OF COLD WORK

A MANAGEMENT MODEL, IMPLEMENTATION AND EFFECTS
TANJA RISIKKO

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A management model, implementation and effects

Academic dissertation to be presented with the assent of the Faculty of Technology of the University of Oulu for public defence in Raahensali (Auditorium L10), Linnanmaa, on 19 September 2009, at 12 noon

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Abstract

Cold is a very common physical risk factor in workplaces in circumpolar regions. Cold has many detrimental effects on human health and performance, and on the safety, quality and productivity of work. In this study a systematic general Cold Risk Management Model was developed, applied and evaluated. The model can be integrated in a company’s or an organization’s occupational safety, health, environment and quality (SHEQ) management systems and practices in workplaces. The Cold Risk Management Model and methods were later included in ISO 15743 Ergonomics of the thermal environment – Cold workplaces – Risk assessment and management. The Cold Risk Management Model and methods were applied in two case company’s SHEQ systems and practices in the fields of construction and maritime administration and services. Based on the case studies, the concrete cold risk management activities and the personnel training campaign resulted in immediate positive results and improved attitudes towards further development. At the national level, working in the cold was estimated to increase personnel costs in the construction industry annually by €50M, which is 3% of the industry’s annual personnel costs. This study also showed that the Cold Risk Management Model and methods are profitable. In the case construction company, the savings achieved by cold risk management activities at a construction site were 2.5 time the costs of those activities. A follow-up study in the case company in the field of maritime administration and services showed that implementation and dissemination of the Cold Risk Management Model and methods require systematic work also after the initial development process. The implementation process could and should be enhanced by early establishment of organization-wide guidelines, visible concrete actions, a training campaign and use of necessary external experts. This study also presents a Safety Management Matrix Model for analyzing development and implementation activities during the process time span.

Keywords: cold risk management, cold work, effectiveness, ergonomics development, evaluation, implementation, occupational safety and health management systems, productivity, quality management, safety management, SHEQ
Acknowledgements

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On board S/Y Liberty, June 2009
Tanja Risikko
Glossary of terms

Cold risk    Cold-related health, performance and safety risks in work (Mäkinen & Hassi 2002).
Cold work    Work can be considered as cold work when the ambient temperature is below +10… 15°C or if a person has cold-related symptoms when doing the work (BS 9815, DIN33405).
Continuous improvement
   A principle in quality management, developed largely by Dr. Deming in the 1950’s (Walton 1986).
Corporate responsibility (CR) or Corporate social responsibility (CSR)
   An active, voluntary responsibility, built upon economic, environmental and social principles (Otala & Ahonen 2003).
Effectiveness
   The degree to which a company has reached its goals by using available resources (Kreitner 1991). An organization’s productivity, adaptability, involvement, continuity, responsiveness to stakeholders or degree to which the set aims have been reached (Nurmi & Kontiainen 2000, Scheerens & Bosker 1997).
Impact       To have an impact or strong effect (on) (Collins Concise Dictionary 2000). The term impact has many meanings, depending on the purpose and the target under study. Impact can be evaluated on an individual, an organization, or on society. (Linna 2001).
Implementation process
   A process in which a developed system, practice, innovation or new technology is implemented and disseminated to the whole organization (Eason 1990).
Multi-component development process
   A development process that is intended for making changes in more than one issue (Lindbäck et al. 2006, Silverstein & Clark 2004).
Occupational health and safety
   Conditions and factors that affect the well-being of employees, temporary workers, contractor personnel, visitors and any other person in the workplace (OHSAS 18001).
Occupational safety

The protection of workers' lives and physical well-being by eliminating or controlling risks in the working environment or the system of work within which workers operate (ILO Thesaurus. http://www.ilo.org//thesaurus/defaulten.asp).

OSH management system, OH&S management system

Part of the overall management system that facilitates the management of OSH risks associated with the business of the organization. This includes the organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving and reviewing and maintaining the organization’s OSH policy (OHSAS 18001).

PDCA model

A quality management model introduced by Dr. Deming. The letters PDCA refer to the four phases of the continuous improvement cycle: Plan, Do, Check and Act. The model is widely used in quality management and development work (Dale 2007).

Productivity

The relation between the input used to achieve a certain output (Kreitner 1991).

Research-assisted development


Risk

Combination of the likelihood and consequences of a specific hazardous event occurring (OHSAS 18001).

Safety

Freedom from unacceptable risk or harm (ISO/IEC 2004).

SHEQ management system

Integrated safety, health, environment and quality management system. Integration is viewed as implementation of a single system in the whole organization, as combining two or more systems through their similarities, or as organization-wide integration of all management systems with the policy and objectives of each system aligned to the overall policy (Wilkinson & Dale 2007).

Total Quality Management (TQM)

Application of quality management principles to all aspects of the organization, including customers and suppliers, and their integration with the key business process. (Dale et al. 2007).
Well-being at work (also wellbeing or wellness at work)

A holistic term that combines the physical, psychological and social aspects of health and safety at work (Otala & Ahonen 2003). It aims for comprehensive actions for promoting the health, safety, and well-being of the workforce, simultaneously with the productivity and success of the company (Anttonen & Räsänen 2008).
## List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>CR</td>
<td>corporate responsibility</td>
</tr>
<tr>
<td>CSR</td>
<td>corporate social responsibility</td>
</tr>
<tr>
<td>CWAP</td>
<td>Cold Work Action Program</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>OHC</td>
<td>occupation health care</td>
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<tr>
<td>OHSAS</td>
<td>specification for occupational safety and health management system</td>
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<tr>
<td>OS</td>
<td>occupational safety</td>
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<tr>
<td>OSH</td>
<td>occupational safety and health</td>
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<tr>
<td>PDCA</td>
<td>Plan – Do – Check – Act. A quality development model</td>
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<tr>
<td>PPD</td>
<td>personal protective device</td>
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<tr>
<td>PPE</td>
<td>personal protective equipment</td>
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<tr>
<td>SHEQ</td>
<td>safety, health, environment and quality (management) system</td>
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<td>TQM</td>
<td>total quality management</td>
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List of original articles


The specific contribution of Tanja Risikko in the original articles:

I Development of the Cold Risk Management Model and the cold risk management plan, evaluation of the usability of the Cold Risk Management Model and cold risk management plan.

II Leading the process for applying the Cold Risk Management Model and methods in the case company’s SHEQ management system and in the practical occupational safety activities in the case company’s construction sites.

III Calculation of costs and savings of the cold risk management activities, participation in the expert group for identifying cold-related costs in the construction industry.

IV The practical cold risk management trials in the case company, the implementation plan, evaluating the development and implementation process and its effects in the case company.

Some unpublished results are also presented in the thesis.
Contents

Abstract
Tiivistelmä
Acknowledgements 7
Glossary of terms 9
List of abbreviations 13
List of original articles 15
Contents 17
1 Introduction 21
2 Review of the literature 25
  2.1 Work in the cold ................................................................. 25
    2.1.1 Cold exposure and cold work ........................................ 25
    2.1.2 Human thermoregulation and cooling ............................ 26
    2.1.3 Effects of cold on human performance and health .......... 27
    2.1.4 Effects of cold on safety, productivity and quality of work ... 29
  2.2 Safety, health, environment and quality management ......... 31
    2.2.1 Total quality management (TQM) and continuous improvement .............................................. 31
    2.2.2 Occupational safety and health (OSH) management ....... 33
    2.2.3 Well-being and safety as an investment ......................... 35
  2.3 Development processes ...................................................... 37
    2.3.1 Development work and intervention studies ................. 37
    2.3.2 Implementation, dissemination and diffusion ................ 39
    2.3.3 Results, effects, impacts and evaluation ....................... 41
    2.3.4 Actors ....................................................................... 43
  2.4 Guidelines and methods for OSH activities in cold work ....... 43
3 Cold work action program 1997–2001 45
  3.1 Aims and structure of the program ..................................... 45
  3.2 Implementation, dissemination and evaluation of the CWAP’s results ......................................................... 46
4 Objectives of the study 49
  4.1 General objective and theoretical framework ....................... 49
  4.2 Specific aims ...................................................................... 51
5 Materials and methods 53
  5.1 Progress of the study ......................................................... 53
5.2 Development of a general Cold Risk Management Model and cold risk management methods (I) .......................................................... 55
  5.2.1 Developing the model and methods ............................................. 55
  5.2.2 Evaluating the usability of the Cold Risk Management Model and methods in workplaces ...................................................... 55
  5.2.3 Evaluation of the model and methods by OS and OHC professionals ................................................................................. 57
5.3 Cold risk management in a construction company (II) ...................... 57
  5.3.1 Case company YIT ...................................................................... 57
  5.3.2 Development process and methods .............................................. 58
5.4 Analyzing the economic effects of cold work and cold risk management (III) ..................................................................................... 60
5.5 Evaluating the implementation process and long-term effects of cold risk management at the FMA (IV) ................................................... 61

6 Results 67
  6.1 A systematic general model for managing cold risks (I) ..................... 67
  6.1.1 Cold Risk Management Model ..................................................... 67
  6.1.2 Cold risk management methods .................................................... 67
  6.1.3 Usability of the model and methods ............................................. 72
  6.2 Applying the Cold Risk Management Model in the case company YIT (II) .................................................................................... 73
  6.2.1 Cold risks in construction work .................................................... 73
  6.2.2 Immediate development results at the pilot sites .......................... 74
  6.2.3 Cold Risk Management Model and methods in the case company’s SHEQ management system and practices .......................... 76
  6.3 Economic effects of cold work and cold risk management (III) .......... 78
  6.3.1 Additional personnel costs caused by cold ................................... 78
  6.3.2 Profitability of cold risk management .......................................... 80
  6.4 Implementation and sustainability of the development results in case organization FMA (IV) ................................................................. 81
  6.4.1 Outcomes, implementation and influential factors ....................... 81
  6.4.2 Changes in perceived cold-related risk factors and effects .......... 83
  6.4.3 Safety Management Matrix .......................................................... 86

7 Discussion 89
  7.1 Results and their implications and limitations ................................... 89
  7.1.1 Managing OSH risks in cold work– a systematic approach .......... 89
  7.1.2 Contribution to ISO 15743 ............................................................. 90
7.1.3 Applying the Cold Risk Management Model and related methods in the case companies’ SHEQ systems and practices................................................................. 90
7.1.4 Costs of cold work - profitability of managing cold risks .......... 92
7.1.5 Improving implementation and effectiveness........................ 94
7.1.6 Matrix model for development, implementation and evaluation ......................................................................................................................... 96
7.2 Utilization and dissemination of the results .............................. 96
7.3 Suggestions for further studies.................................................... 98

8 Conclusions .......................................................... 99
References ......................................................... 101
Appendices ....................................................... 113
Original articles ................................................ 139
1 Introduction

Cold is a physical risk factor at workplaces. It is very common in outdoor work, especially in countries in the circumpolar regions. Cold may also be a risk factor in an indoor work environment, for example in the food industry or in cold storage. Work is considered cold work already when the ambient temperature is below +10…15°C or when a person has cold-related symptoms at work (BS 7915, DIN 33403–5). Cold has many detrimental effects on both human health and human performance (Hassi 2005, Holmér 1998, Mercer 2003, Mäkinen et al. 2005, Oksa 1998, Palinkas et al. 2005). In northern regions, where the winter period is long, the effects of cold are often accompanied by wind, wetness, cold materials, darkness and icy surfaces. The adverse effects of cold are also reflected in the safety, quality and productivity of work. (Klen 1992, Pekkarinen 1994, Ramsey et al. 1983.)

Traditionally, a cold environment has not been systematically recognized as an occupational risk factor. During the last decades, however, guidelines, policies and standards have been created for assessing occupational risks related to various thermal environments and for reducing them. There are also recommendations for protective measures against cold-related adverse effects. These recommendations refer to, for example, various technical preventive measures or protective clothing and personal protective equipment (PPE). (BS 7915, DIN 33403–5).

However, cold conditions and cold work should be taken into consideration more systematically in the occupational health and safety (OSH) management and practices of an enterprise. In discussions between research organizations, it was noted that there is no comprehensive set of methods or model for assessing and managing cold in a complementary way in companies and workplaces. An ISO/TC 159/SC5/WG1 work group was founded in 1998 to prepare a new standard for this purpose. The work group was chaired by research professor Juhani Hassi from the Finnish Institute of Occupational Health. The standard to be prepared was given a number, ISO WD 15743. (Kylmätyöohjelma 2001.)

The Finnish Institute of Occupational Health (FIOH) conducted a national Cold Work Action Program (CWAP) in 1997–2001. The purpose of the program was to apply cold-related scientific knowledge in practice in cold work as well as in leisure time activities. This was done by research, by development work in the target companies and organizations, by information and training, and by method development.
The CWAP developed methods for assessing cold-related health and safety risks at workplaces, for managing cold-related health and safety risks at workplaces, for training and informing workers, foremen and OSH personnel, for implementing necessary occupational health care (OHC) activities related to the cold work and for evaluation. The method development process was closely connected to the preparation of ISO WD 15743. The method development ran hand in hand with research-assisted development work in the CWAP’s cooperation companies. Specific development projects were targeted to companies involved in cold indoor or outdoor work. The development work was based on the needs of the enterprises and it was carried out in real work environments. The usability of the methods was tested and evaluated in real work environments by the researchers and the companies’ key persons during the development phase, and the feedback was utilized immediately. (Kylmätyöohjelma 2001). In addition, an international project was carried out to evaluate and further refine the methods in various types of cold work (Risk assessment and management of cold-related hazards in arctic workplaces 2001). In the method development work, Tanja Risikko was responsible for developing a systematic model for cold risk management as a part of a company’s OSH or SHEQ management system and for developing practical methods for managing cold risks in different workplaces. (Kylmätyöohjelma 2001.)

The effects of cold risk management activities are not very easy to measure. As investments in occupational safety and health are increasingly considered as investments in the personnel (Otala & Ahonen 2003), there is a need for measures with which to evaluate these effects in general and also the economical consequences of OSH activities and ergonomics development processes. In the same way, safety, health, environment and quality (SHEQ) management systems should also include measures for evaluating the effects and profitability of cold risk management activities in a company.

Neither the implementation and dissemination of cold risk management activities after the initial development and testing phase nor the long-term effects of these measures have been studied. The implementation process of any new system requires systematic work in a company. Especially in a large organization, the implementation process takes time and is always affected by various internal and external factors (Eason 1990, Fullan 1991). There are many methods for promoting the implementation process, such as the involvement of top management, clear process ownership and systematic training of the personnel.
This thesis presents the development, implementation and evaluation of a systematic model and methods for managing cold-related health and safety risks in different types of cold outdoor and indoor workplaces. The model and methods were developed to be compatible in the most common safety, health, environment and quality (SHEQ) management systems and practices. The usability of the practical methods was evaluated in cold outdoor and indoor work and by an international group of occupational safety and health professionals. The Cold Risk Management Model and methods were integrated into the SHEQ management systems and practices of two case companies in development projects, and the immediate results were evaluated. The additional cold-related personnel costs were evaluated in one case industry in Finland, and the profitability of cold risk management was evaluated in one case company. Finally, the development and implementation process, results and long-term effects of cold risk management were evaluated in one case company.
2 Review of the literature

2.1 Work in the cold

2.1.1 Cold exposure and cold work

During the winter season a majority of the Nordic population is exposed to cool or cold temperatures. The annual number of days with an average temperature lower than +10°C varies between 180–270 in Finland. A population study in Finland demonstrated that the average self-reported cold exposure time is roughly 4% of the total time, on average 0.3h/week. (Mäkinen et al. 2006b). Occupational cold exposure affects more than 30% of the working population in Finland, in both outdoor and cold indoor work. The largest numbers of workers exposed to cold in Finland are in the construction industry, agriculture and forest industry, process industry, transport industry and services. The longest exposure times occur in construction and maintenance work (>20h/week). Workers in the agriculture and forest industry, process industry and traffic as well as military personnel are exposed to cold more than 15h/week. (Hassi et al. 1998.)

Cold exposure can be described by different types of cold exposure. Outdoor cold exposure is perhaps the most common type of cold exposure. It is seasonal and its length and severity are determined by local climatic conditions. Wind, wetness and cold materials are often present. Indoor cold exposure is found in cold storage and in industry, such as the food processing industry, where fresh foodstuff is processed at temperatures of 0–10°C and frozen products at temperatures below -20°C (Oksa et al. 2006). Changing environmental conditions are typical in many occupations, for example in mail delivery or in delivery transport. Changing environmental conditions and activity levels require continuous thermoregulatory adjustments, which may cause a special type of stress. Contact with cold surfaces is common in activities where manual labor is required in handling objects. Contact with cold liquids or immersion in cold water are especially severe forms of cold exposure. (Geng et al. 2001.)

According to occupational health and safety standards, work can be considered cold work already when the ambient temperature is below +10… 15°C or when a person has cold-related symptoms at work (BS 9815, DIN33405).
2.1.2 Human thermoregulation and cooling

Efficient and optimal functioning of the human body requires body and tissue temperatures to be within a narrow range. The core temperature of a human is normally 37°C±1–2°C. Body temperatures below and above this range are called hypothermia and hyperthermia. The temperature of superficial tissues and skin varies over a wider range. A human is in thermal balance when heat production equals heat loss. Heat produced by the body is dissipated to the surroundings at a rate that is determined by the properties of clothing and the following climatic factors: air temperature, mean radiant temperature, air velocity (wind) and humidity. (Holmér 1994b, Parsons 1993.)

Heat is generated in the body by the combustion of fat and carbohydrates, mostly in muscle tissue. A person’s metabolic heat production varies widely. It can be classified in various ways, for example at rest, very light work, light work, moderate work, heavy work and very heavy work (ISO 8996). Heat production at rest is <65W/m² (related to a person’s skin area), which equals 90–100W for an average sized person. In moderate physical work or exercise, such as walking at a speed of 3–4.7km/h, heat production is 130–195W/m². In very heavy physical work or exercise a person’s heat production is > 260W/m². (ISO 8996)

Heat produced in the tissues is transferred to the environment by radiation, convection, conduction, evaporation and respiration. In cold conditions, the primary source of heat loss is convection by moving air or wind (50–80% of all heat loss). The body’s extremities are particularly susceptible to great heat loss due to their small mass compared to their relatively large skin surface area. Heat is radiated from the surface of the body to colder surfaces in the environment. In cold conditions, with adequate protective clothing, maximum radiant heat loss is 20% of total heat loss. The body may also gain some heat by absorption of solar radiation. (Holmér et al. 1997). In contacts with cold objects, heat is lost by conduction (Geng at al. 2001). Evaporation is the most powerful means of losing heat from a warm body. However, with thick clothing, it is not efficient. (Holmér et al. 1997). As a result of cold exposure, different types of cooling may occur: whole body cooling, cooling of the extremities such as the hands, the feet the nose and the ears, or cooling of the respiratory tract (Mäkinen 2007). Contact cooling is common in manual work with cold objects (Geng et al. 2001.)

In cold conditions, a person’s physiological responses are directed to preserving the body’s heat content. The peripheral blood vessels constrict, which reduces heat loss. Muscle tension increases and eventually turns into spontaneous
additional heat production by shivering. Due to the human thermoregulation system, the head stays warm in all ambient temperatures, and it may thus lose large amounts of heat. (Holmér et al. 1997.)

2.1.3 Effects of cold on human performance and health

Cold may cause adverse effects on human performance. Cooling impairs physical and mental performance in many ways. At its mildest, cooling causes unpleasant sensations and thermal discomfort. The adverse effects of cold increase when the temperature drops below -10°C (Raatikka et al. 2007). Wind, wetness and cold materials increase the cooling rate of skin and tissues, and thus increase the adverse effects of cold (Hassi 2005, Holmér 1998, Mäkinen 2007).

Cooling affects all components of muscular performance. Muscle coordination and manual dexterity are impaired, physical load increases, strength, endurance, coordination and velocity decrease (Enander 1984, Oksa 1998). Muscular activity can be either dynamic (with visible movements) or isometric (no visible movements). In general, the ability to perform dynamic exercise is more easily disturbed by cooling than is isometric exercise. Cooling decreases dynamic performance about 2–10%/°C decrease in muscle temperature. At muscle temperatures below 27°C, an 11–19% decrement in isometric force may occur. Contrary to force, in isometric performance endurance may even be increased by cooling and development of fatigue is slowed. (Bergh 1980, Ellis 1982, Oksa et al. 1995, Oksa 1998, Provins et al. 1960). Manual performance decreases in several ways (Table 1) (Enander 1984). Postural sway is also increased by cold exposure (Mäkinen et al. 2005). Wind, wetness and cold materials accelerate the cooling rate of skin and tissues, and thus increase the adverse effects of cold. Severe cold exposure may also impair physical performance by affecting the respiratory tract. (Holmér 1998, Mäkinen 2007.)

Clothing and personal protective devices (PPDS) are used to prevent body cooling. On the other hand, the use of protective clothing may sometimes also have disadvantages. Due to their weight and bulkiness, clothing and other protective garments may decrease human performance by disturbing sensory functions, impairing dexterity, limiting the range of movements and increasing the energy costs of work. Another issue is that uncomfortable PPDs may not be worn at all. (Berquist & Abeysekera 1994, Rissanen 1998.)
Table 1. Effects on manual performance, function and perception at different skin temperatures (Enander 1984).

<table>
<thead>
<tr>
<th>Local skin temperature (°C)</th>
<th>Effects of temperature on manual function</th>
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<tr>
<td>32–36</td>
<td>Optimal temperature</td>
</tr>
<tr>
<td>below 32</td>
<td>Impairment of perception of roughness</td>
</tr>
<tr>
<td>28 (muscle)</td>
<td>Decrement of muscle power</td>
</tr>
<tr>
<td>20–27</td>
<td>Decrement in accuracy and endurance</td>
</tr>
<tr>
<td>12–16</td>
<td>Decrement in manual dexterity</td>
</tr>
<tr>
<td>16</td>
<td>Pain (whole hand cooling)</td>
</tr>
<tr>
<td>10</td>
<td>Pain (small area cooling)</td>
</tr>
<tr>
<td>8</td>
<td>Loss of sensitivity</td>
</tr>
<tr>
<td>6</td>
<td>Nervous block</td>
</tr>
<tr>
<td>6–7</td>
<td>Loss of sensations</td>
</tr>
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</table>

The effect of cold on cognitive performance is a complex issue. Studies show inconsistent effects of cold on cognitive performance in moderate, non-hypothermic cold exposure (Palinkas et al. 2005, Mäkinen et al. 2006a). Cold causes discomfort, which may be a distracting factor of work performance (Davis et al. 1975, Vaughan 1977, Mäkinen et al. 2006). On the other hand, mild cooling may increase the general arousal level, which improves performance. However, a further increase in discomfort will lead to an increased number of errors and longer reaction times. (Ellis 1982, Enander 1987, Mäkinen et al. 2006a). In addition, living in a cold and dark environment may cause changes in mood and further decrease cognitive and physical performance over a longer term (Palinkas 1996).

Cold affects also human health. Cold exposure may be a triggering factor of certain diseases and may aggravate symptoms of many chronic diseases (Mercer 2003, Hassi 2005). Cold may cause an increased amount of symptoms, such as pain, white fingers, respiratory or musculoskeletal symptoms, in healthy individuals (Hassi et al. 1998, Raatikka et al. 2007). These symptoms become more pronounced at temperatures below -10°C (Raatikka et al. 2007). In heavy work, cold-related problems in the respiratory system may start to appear at ambient temperatures below -15°C (Giesbrecht 1995). Cold air is a trigger of cold air-provoked respiratory symptoms. The mechanisms behind these symptoms vary considerably and mainly depend on the individual’s susceptibility and the ventilation level during cold exposure. (Koskela 2007). Musculoskeletal symptoms are common among those who work in cold conditions (Jin et al. 2000, Pienimäki 2000). Sormunen et al. (2006) studied repetitive meatpacking work in
a cooled work environment. According to this field study, muscular strain was mainly related to the intensity of work movements, not to upper extremity cooling. This was most likely due to sufficient thermal protection in the upper extremities. (Sormunen et al. 2006). However, repetitive work in the cold causes higher EMG activity and fatigue than does repetitive work in thermo-neutral conditions and might therefore pose a higher risk of overuse injuries and eventually, musculoskeletal disorders. It was also found that increased muscle strain and fatigue during low-intensity repetitive work may be restored, at least partially, by intermittently increasing the workload and thus breaking the monotonous work cycle. (Oksa et al. 2006.)

Cooling injuries, such as frostbite, hypothermia and other cold injuries, are related to body cooling. Frostbite generally occurs in the most peripheral parts of the body. (Hassi & Mäkinen 2000). The annual occurrence of frostbite among Finnish people is rather high, 2.5 per 100,000 inhabitants (Juopperi et al. 2002). Frostbite cases generally increase in accordance with the length of the winter and also increase in daily cold exposure (Juopperi et al. 2003). According to a study by Ervasti et al. (2004), the life-time occurrence of frostbite was 44% among young Finnish men in military service. A synergistic increase in frostbite cases was reported in cold-provoked white-finger syndrome, smoking and hand vibration (Ervasti et al. 2004). Living in cold conditions, and heat spells on the other hand, also increase the human mortality rate (Keatinge 1997, Näyhä 2005, Näyhä 2007). Hypothermia is not common in work conditions. However, in work situations with prolonged exposure to cold, wetness and wind, cooling of the body may continue, and cold injuries like frostbite and hypothermia may occur (Brändström & Björnstig 1997, Hassi & Mäkinen 2000). Cold may thus be a life-threatening risk factor even in work situations, especially if a person is working alone, gets lost in the terrain or is injured.

2.1.4 Effects of cold on safety, productivity and quality of work

As described above, cold affects physical and cognitive performance in many ways. The outdoor work environment changes due to cold. In northern areas, such as in the Nordic countries, the cold climate is often connected to wind, wetness, the dark winter season and icy, slippery surfaces, which also increase the risks of occupational accidents. Furthermore, cold may also increase health and performance risks caused by other occupational risk factors, such as chemicals or

A cold environment is often an additional risk factor in occupational accidents, and it is not always mentioned in accidents reports. Anyhow, many earlier studies have shown that the safety and productivity of work decrease when the ambient temperature decreases or increases from the thermal comfort zone (Vernon 1919, Vernon et al. 1927). According to Ramsay et al. (1983), the ambient temperature has a statistically significant effect on the so-called unsafe behavior index (UBI). The minimum UBI values occur in the ambient wet bulb globe temperature (WBGT) zone of 17–23°C. The proportion of unsafe behavior rises if the ambient temperature decreases or increases from the preferred range (Ramsay et al. 1983). It was also shown that the number of slip and fall accidents increases at ambient temperatures around and below 0°C (Hassi et al. 2000). According to a longitudinal survey at Kostamuksha construction sites in 1978–1983, the frequency of occupational accidents was highest from September to November and the severity of the accidents was highest in February to April and in October. The severest accidents happened in February. (Pekkarinen & Anttonen 1989.)

Productivity is defined as the relationship between the input used to achieve a certain output and the output itself. The input can be expressed in monetary or volume units, such as consumed energy or human work hours. Effectiveness, again, is a broader concept that describes the degree to which a company has reached its goals by using available resources. Effectiveness can be defined in many ways. Effectiveness criteria may include the effectiveness of time resources, cost-efficiency and the satisfaction of clients, owners and personnel (Kreitner 1991, Liukkonen 2006.)

Cold conditions increase the need for energy, machinery and equipment. For this reason outdoor work is more expensive in cold than in warm conditions. The economic losses due to cold work in northern regions are large. For example, in the construction industry, construction time is calculated by using a seasonal factor of 0.9 in the summer and 1.1 in the winter compared with average construction time. (Talvirakentaminen 1991). So far, the focus has mainly been on the additional costs caused by additional energy need or additional technical solutions. The planning instructions of the construction industry “Winter Work and Costs” (Talvityöt ja –kustannukset 1996), divides the additional costs into different cost categories. The term “human work” covers all the costs caused by
the personnel. The reasons for the additional personnel costs during the winter have not been studied comprehensively.

In Finland, occupational cold exposure is most common in the construction industry and in agriculture. The perceived cold-related detrimental health and performance effects are also high in these industry sectors (Hassi et al. 2000). According to statistics, the frequency of occupational accidents and the prevalence of musculoskeletal symptoms are higher among construction workers than among workers in all industry sectors in general (Juntunen et al. 2000, Mäkelä et al. 1997, Työtapaturmat ja ammattitaudit 2008).

Cold conditions are related especially to musculoskeletal disorders and cardio-vascular diseases, which are common among the Finns in general. In the long run, the increased morbidity during the cold season may cause additional costs due to early retirement of the labor force. (Hassi et al. 2000). The largest sickness-related costs in Finland in general result from early retirement. The biggest proportion of retirement costs comes from lost labor input. (Ahonen 1996.)

2.2 Safety, health, environment and quality management

2.2.1 Total quality management (TQM) and continuous improvement

The concept of Total Quality Management (TQM) involves the application of quality management principles to all aspects of an organization, including customers and suppliers, and their integration with the key business process. TQM emphasizes the balance between technical, managerial and personnel issues. It is a company-wide approach to quality, with improvements undertaken on a continuous basis by everyone in the organization. (Dale et al. 2007). TQM originated in Japanese industry in the 1950’s and has steadily become more popular in the West since the early 1980’s (Deming 1986, Walton 1986). According to Dale et al. (2007), the key elements of TQM are the commitment and leadership of the chief executive officer, planning and organization, use of tools and techniques, education and training of the personnel, involvement of the personnel, teamwork, measurement and feedback, and ensuring that the culture is conducive to continuous improvement activity (Dale et al 2007).

The principle of continuous improvement was developed largely by Dr. Deming in the 1950’s. The Shewhart cycle, the PDCA model, the PDCA cycle and the Deming wheel all refer to the quality management model introduced by Dr.
Deming and used expansively in Japan since the 1950’s (Deming 1986). The letters PDCA refer to the four phases of the cycle: *Plan*, *Do*, *Check* and *Act* (Figure 1). The model has been widely used in quality management and development work. The principle of continuous improvement is included in TQM and is common also in the most popular international standards and specifications of quality and environment management systems, such as ISO 9000 Quality Management Systems: Guidance for Performance Improvements; ISO 9001 Model for Quality Assurance in Design, Development, Production, Installation and Servicing; ISO 9004 Guidelines for Performance Improvements; and the environmental management standard, ISO 14001 Environmental Management Systems – Requirements with guidance for use (ISO 9000, ISO 9001, ISO 9004, ISO 14001).

The PDCA model was elaborated and further developed by Hutchison (1997). The approach is called “The QC Story”. Like the PDCA cycle, the QC Story is also applicable in ergonomics development processes. The seven steps of the QC Story are: define the safety opportunity or problem, observe the process, analyze causes (plan), act on the causes (do), check the results, standardize the changes (check), implement the changes (act). The QC Story also includes documentation and evaluation of the effects, side effects and economic consequences. (Hutchison 1997.)

![Fig. 1. The principle of the PDCA cycle with the seven steps of QC Story.](image-url)
2.2.2 Occupational safety and health (OSH) management

According to international and national laws and regulations, the employer is responsible for assessing occupational risks and for undertaking measures to remove or prevent them (Occupational safety and health act 738/2002, Council Directive on the introduction of measures to encourage improvements in the safety and health of workers at work 89/391/EEC). In addition, the Occupational Health Care Act in Finland (Occupational Health Care Act 1383/2001) defines occupational health care activities also in regard to various risk factors. There are also risk-specific acts and recommendations, industry-specific safety rules and practices and trade agreement-based norms and practices.

Systematic occupational safety and health (OSH or OH&S) management enables a company to carry out successful occupational health and safety practices and improve the safety culture at the workplace. The most common occupational health and safety management standards and specifications in Europe follow the principle of continuous improvement (BS 1996, Kjellén 2000).

One of the most well known European occupational health and safety management systems is the OHSAS 18001 occupational health and safety management system specification. It was developed to be a recognizable OSH management system (or OH&S management system) specification against which the OSH management systems of organizations could be assessed and certified (OHSAS 18001). It gives the requirements for an OSH management system to enable an organization to control its OSH risks and improve its performance. It is accompanied by the OHSAS 18002 guidelines for implementation (OHSAS 18002). OHSAS 18001 is also compatible with the ISO 9001 and ISO 14001 standards (ISO 9001, ISO 14001). The principle of continuous improvement is presented in Figure 2 (OHSAS 18001).
During the last ten years there has been a shift towards more comprehensive management systems that integrate the quality, environment and occupational safety and health management systems of an enterprise. These integrated management systems are often called safety, health, environment and quality systems (SHEQ). According to Wilkinson and Dale (2007), this integration is viewed in a number of different ways: as an implementation of a single system throughout the whole organization, as combining two or more systems through similarities in their structure, or as an organization-wide integration of all management systems with the policy and objectives of each system aligned to the overall policy (Wilkinson & Dale 2007). In this thesis the term SHEQ management system is used for the last-mentioned meaning.

A work system, again, involves a combination of people and equipment within a given space and environment and the interactions between these components within a work organization. ISO 6385, ergonomic principles in the design of work systems, aims at improving the interface between individual users and the components of their working situation - such as tasks, equipment, workspace and environment - right from the beginning of the design process. The standard provides a framework for the design of new or existing work systems, with a view to facilitating the work behavior and well-being of users. (ISO 6385.)
Occupational safety (OS) has become an especially important and more complex issue in shared workplaces, where many contractors and subcontractors work in the same workplace (Sulasalmi & Väyrynen 2003). In the most severe terms, shared workplaces comprise a common occurrence environment in terms of fatal occupational accidents (Lappalainen et al. 2007). There are methods and tools for improving OS in shared workplaces. In Finland, a National Occupational Safety Card (OSC) system and training was developed and established to enhance the general level of occupational health and safety, especially at shared workplaces (Sulasalmi & Väyrynen 2003).

2.2.3 Well-being and safety as an investment

On average, we spend 24–60% of our daily hours at work (Csikszentmihalyi, 1997). Well-being at work can be defined in many ways. It is a holistic term that combines the physical, psychological and social aspects of health and safety at work (Otala & Ahonen 2003). Well-being at work aims for comprehensive actions for promoting the better health, safety, and well-being of the workforce, simultaneously with the productivity and success of the company and enterprise (Anttonen & Räsänen 2008). The terms well-being at work and wellness at work are synonyms to the term well-being at work. The term “work engagement” is also used to describe a condition, where the employee feels energetic, committed and capable and has a good professional self-esteem (Maslach & Leiter 1997). In this thesis the term well-being at work is used.

The competence of an enterprise consists of several factors: quality, productivity and cost-efficiency (Otala & Ahonen 2003, Sydänmaanlakka 2005). The main reasons for a company or an organization to improve the well-being and safety of its employees are laws and regulations, social and ethical reasons and economic reasons. Inputs to occupational safety, health and well-being at work are increasingly seen in enterprises as investments in the personnel. To encourage this approach, the SHEQ management system should also include means to evaluate the effects and economic consequences of risk management and SHEQ practices.

Several management models and evaluation criteria emphasize balanced goals and criteria instead of just pure historical economic data. In the Balanced Scorecard Model (BSC), set goals and evaluation criteria are divided into four groups: economic results, customer results, efficiency goals and growth goals. The growth goals also include goals related to the well-being, skills and
innovativeness of the personnel (Kaplan & Norton 1996). A company also has
responsibilities towards society. These responsibilities include responsibility for
the personnel and the environment. Corporate responsibility (CR), or corporate
social responsibility (CSR), is an active, voluntary responsibility built upon
economic, environmental and social principles (Otala & Ahonen 2003).

The costs of occupational accidents are high. According to the EU European
Agency for Health and Safety at Work, an estimated 4.6 million occupational
accidents happen every year in the European Union. At the time of the report, lost
working hours equaled 2.6–3.8% of the collective EU gross national product
(GNP) every year. (Economic Impact of Occupational Safety and Health in the
Member States of the European Union (2001). Furthermore, Rikhardsson &
Impgaard (2002) have evaluated that only two thirds of all the costs caused by an
occupational accident are visible to the accounting systems, while one third
remain hidden (Rikhardsson & Impgaard 2002). According to Aaltonen et al.
(2006), the connection between the quality of the working environment and
productivity is well understood by various expert and employee groups of the
companies. However, only 54% of the survey respondents had enough cost
information when making decisions about safety activities. Forty percent of the
respondents also agreed with the statement that OSH activities and investments
are not considered generally productive in their company. (Aaltonen et al. 2006).
Despite new technological innovations, the number of occupational accidents has
not decreased during the last few years, as it has done since the beginning of the
1900s. One of the reasons may be the increased amount of subcontracting work,
which has made management practices and control more complicated.
(Lappalainen et al. 2007). The costs of occupational accidents accumulate in the
supply chains of companies. If delivery times are tight, accidents may also cause
disturbances in the supply chain. (Aaltonen et al. 2006.)

The average costs of sick leaves are approximately 5% of the salary costs of
an enterprise in Finland (Otala & Ahonen 2003). The Finnish population is also
aging fastest in Europe, and the average retirement age is 57–59 years. It is thus
crucial for national competence to enhance the workability of the labor force as
long as possible. (Otala & Ahonen 2003.)

The amount of productive working time can be increased by targeting
activities that promote health. (Otala & Ahonen 2003). There are only a few
studies that actually show the exact economic effects of changes in the work
environment on economic profits. A successful ergonomic improvement with a
holistic approach and employees' involvement can be very profitable
Changes and benefits often take place over long periods, and are for this reason difficult to measure. However, a number of studies indicate that there is a relationship between ergonomic improvement and improved productivity (Ichinovski et al. 1995) or other positive economic effects (Anderzen & Arnetz 2005, Hendrick 2003, Johanson 1997). According to Ingelgård & Norrgren (2001), a properly planned and implemented learning strategy correlates positively with the quality of working life and economic output in ergonomic improvements (Ingelgård & Norrgren 2001).

2.3 Development processes

2.3.1 Development work and intervention studies

A wide variety of models for workplace interventions and quality or ergonomics development work have been created during the past decades. The principle of continuous improvement is present in many of these models. The PDCA model (Deming 1986) is widely used for a wide variety of development processes. The model presented by Hutchison (1997) may also be used to further refine the process.

Goldenhar et al. (2001) introduced a conceptual, three-phase model for an intervention research process. The intervention research consists of 1) developmental research, 2) implementation research and 3) effectiveness research phases (Figure 3). This model provides a framework for evaluating development and implementation processes, their effects and influencing factors over a long term (Goldenhar et al. 2001). The cyclic approach has been applied widely to various processes, such as in the pedagogic concept of expansive learning, which proceeds in a cycle of learning actions (Engeström 2004).
The term research-assisted development (or research-based development) refers to various types of development approaches, which derive from research results, and on the other hand, produce new conceptual models and knowledge. These different approaches are described by e.g. Alasoini (2005), Arnkil (2004), Engeström (1987) and Greenwood & Levin (1998). The Finnish Workplace Development Programmes TYKE in 1996–2003 and TYKES in 2003–2009 use the approach of research-assisted development, without being strictly committed to any particular approach (Alasoini 2005).

Work environment and ergonomics development processes and interventions may be targeted to make changes in management systems, workers’ skills and attitudes, or equipment and tools (Lindbäck et al. 2006). Multi-component development processes, which are aimed to make changes in more than one of these elements, are shown to be the most effective (Lindbäck et al. 2006, Saarela 1991, Silverstein & Clark 2004). According to the discipline of systems thinking, a system consists of actors, a target and the society in which the activities take
place. A change in one factor is always reflected to the other factors. (Engström 1987, Engeström 2004, Sydänmaanlakka 2005.)

2.3.2 Implementation, dissemination and diffusion

The term implementation process is used to describe the process in which a developed system, practice, innovation or new technology is implemented and disseminated to the whole organization (Eason 1990, Fullan 1991, Väyrynen et al. 2004). The implementation process may be seen as a set of sub-processes. After an innovation or a new practice is born, it is applied in planning and implementing processes, which are followed by standardization and final results (Fullan 1991). Depending of the size and type of the innovation or change, the whole innovation or development process may take from three to ten years from the planning phase to full diffusion of the results through the whole enterprise (Fullan 1991).

Especially in large organizations, diffusion of a new innovation or practices to the whole organization requires systematic long-term work. Implementation of new practices or innovations through the whole organization also requires several enabling or helping factors. The most important helping factors are organizational change and culture, management support, personnel participation and acceptance of the change, thorough planning, reliable equipment suppliers, training and support before and after the implementation phase (Eason 1990, Fullan 1991, Hendrick & Kleiner 2002, Langford & McDonagh 2003, Väyrynen et al. 2004, Whysall et al. 2005, Wilson 1993). Contrary to many other studies, Ingelgård & Norrgren (2001) claimed that top management involvement was not the most important factor of change outcomes. Instead, process factors were of the most importance. (Ingelgård & Norrgren 2001). It is also important that the development and implementation process is visible at the workplace, it has concrete effects, its timing is optimal, the development methods are flexible and expertise is available (Rissanen et al. 2003).

The key barriers or hindering factors of effective implementation of workplace interventions largely relate to the workers’ resistance to change, to the managers’ attitudes towards development, health and safety issues, limited resources and the lack of knowledge (Ljungström 2000, Whysall et al. 2005). Among the biggest hindering factors are extensive reorganizations (Rissanen et al. 2003). According to Ljungström (2000), it is more difficult to implement daily continuous improvement activities at the administrative level of an organization.
than in operative work. (Ljungström 2000). The implementation process should never be considered purely as a technical problem, and the human and organizational factors should always be taken care of. Different stakeholders’ goals need to be met. This is increasingly important in situations where new systems are causing major uncertainty. (Eason 1990.)

There are various strategies for implementing a new system, ranging from the most evolutionary to the most revolutionary (Eason 1990). The most suitable strategy should be selected carefully, depending on the target organization. For example, an approach with phased introduction is appropriate in organizations that have similar functional units spread over a large geographical area. Another strategy emphasizes trials and the following dissemination, which gives the organization an opportunity to prepare itself for the large-scale change. Disregarding the applied strategy, a crucial factor in the implementation process is the degree to which the potential users (or the employees) are involved in the process as early as possible. A mechanism for involving everybody in the process is needed. (Eason 1990.)

In several studies, multi-component development approaches and interventions are emphasized to ensure and fasten implementation and diffusion of the development results in an organization. There should be actions at the various levels through the development project. Strong participation and project ownership by the employees and employers of the target organization are essential and beneficial for success. (Lindbäck 2006, Silverstein & Clark 2004). According to Saarela (1991), proper design and coordination and the involvement of all personnel groups promoted the effectiveness of the intervention program. Sole information campaigns were effective in raising awareness of hazards among workers in the shipbuilding industry, but the actual changes at the construction sites remained relatively modest. Participatory occupational safety programs, including joint goals, training, measurements and feedback, proved to be more successful in improving good housekeeping and safety. (Saarela 1991). In a review by Lehtola et al. (2008), limited evidence was found for the effectiveness of a multifaceted safety campaign and a drug program, but no evidence was found that legislation is effective in preventing injuries in the construction industry (Lehtola et al. 2008).

On the other hand, implementation and diffusion of the results is a complex issue in multi-component processes, while many influential factors may lead to variations in the original plan during the development phase and the implementation phase (Lindbäck 2006, Silverstein & Clark 2004, Väyrynen et al. 2008).
Many workplace interventions are likely to have more diverse effects at the organization level than at the individual level, as the number of subsystems with potentially diverging interests is larger. While it is extremely important to tailor the development activities in and for each individual company, it also makes it more difficult to utilize, transfer and further develop the good practices, products and processes (Mäntyneva et al. 2005). A combination of person-focused and organization-focused development approaches seems to be the most promising (Semmer 2006). While the actions taken in various parts of the system always affect the activities of other parts, the interaction between these activities throughout the development and implementing processes should be studied further (Anderson et al. 2005, Lindbäck 2006).

2.3.3 Results, effects, impacts and evaluation

Development work causes changes, which have effects and impacts on the initial problem (Koskela 1998). Effect as a noun means result (Perelman et al. 2009). It is widely used to describe the changes which have occurred after implementing a new system or practices. Impact is a broad term, which cannot be explained with one single definition. This makes evaluation of impacts difficult and sometimes even unreliable. In addition, the terminology is not standardized. The term impact has many meanings, depending on the purpose and the target under study. We can evaluate impact on an individual, an institute or organization, or on society (Linna 2001). In various evaluation studies, the word effectiveness is used to describe an organization’s productivity, adaptability, involvement, continuity, responsiveness to stakeholders or the degree to which set aims have been reached (Nurmi & Kontiainen 2000, Scheerens & Bosker 1997). In this study, the words result and outcome are used for immediate development outcomes. The word effect is used for the changes that were brought about by the development and implementation results and process in the case companies.

Ergonomics and work environment development projects may have effects on the productivity, quality, well-being and safety aspects of work. The success of an intervention study or a research-based development project is based on two basic principles: the theory behind the intervention is correct and the intervention process or program is carried out successfully. For this reason, both the results and the process should be evaluated in order to shed light on the factors that have influenced the results of the study (Kristensen 2005, Nielsen et al. 2006.)
Due to the long time span and several influencing factors, it is very difficult to evaluate the long-term effects or impacts of a development project or an intervention. Examination of the effects is also time-consuming and unreliable. When evaluating the effects of development work, it may be beneficial to evaluate the results and changes that lead to the effects. (Kantanen 1997). In a multi-component development and implementation process, it is also often difficult to determine the exact point when a change has happened or the reason why it has happened. The evaluation may also be affected by the so-called Hawthorne effect, in which the change appears very effective, not because of the change itself but because the staff is in the “spotlight” and for this reason they respond very positively (Rothlisberger & Dickson 1939). In order to get as comprehensive an evaluation as possible, both quantitative and qualitative methods should be used (Koskela 1998, Rissanen et al. 2003).

However, there are some follow-up studies of systematic models and methods that have been developed for use as tools in various OS and ergonomics monitoring, development and training activities. A TR safety observation method (TR-Mittari) was developed in Finland in the 1990s to be used as a systematic OS observation method in construction work (Laitinen et al. 1999). The TR safety observation method has led to positive improvement in the safety index at a large number of construction sites in Finland. It was shown that there is a statistically significant correlation between the TR index and the contribution margin of the construction sites (Kemppilä et al. 2002). In another study by Simola (2005), a model for safety leadership as a line supervisor's task was developed and tested. The model commits all managers to a shared vision of the safety program and functions as a concrete tool for enhancing the quality of the line manager's safety leadership. The empirical part of the intervention research showed a clear decrease in lost-time injury-frequency rates (LTI) and positive trends in other safety performance indicators. (Simola 2005). In a pre-post study by Saarela (2000), a radical decrease in the accident rate of a shipyard was found after carrying out an occupational safety intervention (Saarela 2000). Positive preliminary results were shown also in the first follow-up study of the Finish Occupational Safety Card (OSC) system. The effects of the OSC alone were difficult to measure, as other measures for improving safety management were implemented simultaneously, but a decreasing trend was shown in the accident frequency rate (LTI) and a positive trend was seen in the quality levels of the early OSC adopters (Väyrynen et al. 2008).
2.3.4 Actors

Multi-component and multi-actor development processes raise the question of various actors’ roles in the development and implementation processes. It is important that the key actors in various personnel groups in the company assume ownership of the change process. This may not always be the case, and many roles are assumed by internal or external experts and facilitators, such as technical designers, development project managers, researchers, ergonomists and trainers. To act successfully, a supporting expert has to play the roles of content expert and change agent, which may be difficult (Eason 1990). Experts and facilitators are important for starting up and initiating a change in behavior. In order to develop successful continuous improvement, the organization’s managers need more profound competence and coaching in work development issues (Ljungström 2005).

Only a few studies discuss the roles and interaction of the various personnel groups and the contributing external experts in the ergonomics development and implementation process.

2.4 Guidelines and methods for OSH activities in cold work

Methods have been developed both for assessing cold-related health and safety risks at workplaces and for preventive and protective measures against cold (Holmér 1993, Holmér 1994a, Holmér 1994b, ISO 15265, Malchaire et al. 1999). Thermal standards provide guidelines for assessment and evaluation methods for body cooling (ISO 11079), thermal strain (ISO 9886), contact cooling (ISO 13732–3), subjective thermal assessments (ISO 10551), heat production (ISO 8996) and required thermal insulation of clothing (IREQ) (ISO 11079). Several of these standards can be used to assess thermal risks caused by cold exposure. Most of these methods are self-contained, but in a comprehensive assessment they should be used in conjunction with each other. Furthermore, the assessment often requires specific measurements. According to Malchaire et al. (1999), cold risks should be identified and analyzed to the extent required to solve the problems. The different levels of the risk assessment procedure may be described, for example, as screening, observation, analysis and expertise levels (Malchaire et al. 1999). Responses to cold vary widely between individuals. This information is needed for medical selection of employees that work in cold environments and for the individual contents of occupational health care (OHC) practices for those
who have minor health-based personal limitations in their ability to work in cold environments. (Hassi et al. 2003). There are no standards specifically for cold-related OHC activities.

There are also environmental standards for cold work environments (BS 7915, DIN 33403–5), but they give a limited amount of practical instructions for assessment and management of cold. They also do not give advice for integrating cold risk assessment and management practices into a company’s general risk assessment and management procedure.

There are also standards and requirements for cold protective clothing. When a set of clothing is used to prevent body cooling and performance decrement, it is a personal protective device (PPD). Selection and use of PPDs and their manufacture should follow the general requirements for personal protective devices. The most important specific requirements and the test procedures for protective clothing against cold, rain or cool conditions are given in the European EN standards (EN 342, EN 343, EN 511, EN 14058).

The available guidelines and standards do not give advice for integrating cold risk management into the company’s general OSH or SHEQ management system. In other words, the continuum from identifying cold-related health and safety risks to managing the risks systematically is lacking.
3 Cold work action program 1997–2001

3.1 Aims and structure of the program

The Finnish Institute of Occupational Health (FIOH) conducted a national Cold Work Action Program (CWAP) in 1997–2001 in order to apply cold-related scientific knowledge to practices in cold work and leisure time activities. This was done through research, development work in the target organizations, method development, and information and training. The overall target group consisted of Finnish people in general. The specific development projects were targeted to companies, involved in cold indoor or outdoor work, companies that guided their customers in cold conditions and vocational education. The industries involved in the development projects were construction, tourism, shipping and maritime industry, transport and maintenance. Total CWAP funding was €2,220,000 and personnel resources totaled 39 work years during 1997–2001. (Kylmätyöohjelma 2001.)

The CWAP development projects were planned and conducted together with the target organizations’ key persons, such as company managers, workplace foremen, workers’ occupational safety delegates and occupational health care personnel. The development work was based on the needs of the enterprises and it was carried out in a context-bound manner in real work environments. Worker training was organized at the workplaces in order to combine theoretical research-based and practical tacit knowledge (Kylmätyöohjelma 2001). System thinking (Engeström 1987, Sydänmaanlakka 2005) was used in the development work and training. Thus, it was important when planning and implementing the changes to involve and train the whole personnel in the new work practices (Kylmätyöohjelma 2001, Sarala & Sarala 1998). During the CWAP, industry-specific training and information material, such as industry-specific cold work guide booklets or planning tools, were produced to be used at the companies and by OSH professionals (Kylmätyöohjelma 2001).

During the CWAP, the method development process was aimed at developing general, usable methods – tools - for assessing and managing cold-related health and safety risks at workplaces, for training and informing workers, foremen and OSH personnel, and for necessary OHC activities related to cold work. The methods utilized and followed the approach of the existing general OSH regulations, available thermal standards and good practices for OSH and OHC activities. The development process was connected to the preparation of ISO WD
Method development ran hand in hand with practical development work in the CWAP’s cooperation companies. The usability of the methods was tested by the researchers and the companies’ key persons during the ergonomics development work in real work environments, and the feedback was used immediately. (Kylmätyöohjelma 2001). In addition, an international project was carried out to evaluate and further refine the methods in various types of cold work (Risk assessment and management of cold-related hazards in arctic workplaces 2001).

The entire set of methods for cold work included the following parts: 1) the cold work assessment procedure and checklist (Mäkinen et al. 2002), 2) the Cold Risk Management Model, the cold work plan and guidelines for selecting concrete cold risk prevention and cold protection measures at the workplaces, 3) instructions and supporting material for personnel training and 4) guidelines for occupational health care activities (Hassi et al. 2003). In this process, Tanja Risikko was responsible for developing a systematic model for cold risk management as a part of a company’s OSH or SHEQ management system, associated with practical methods for managing cold risks in the company’s different workplaces (Kylmätyöohjelma 2001).

3.2 Implementation, dissemination and evaluation of the CWAP’s results

After the CWAP ended, the target enterprises and organizations took care of implementation and dissemination of the initial development results in their own organizations. Especially in large organizations, adoption of new practices requires systematic dissemination work. A need for expert support in implementation and large-scale dissemination work was brought up in the discussions between the key persons of the target enterprises and the experts from the CWAP. A center of excellence was suggested for this purpose. (Hänninen et al. 2001). However, it was not established by the FIOH.

The process and results of the CWAP were evaluated by an international evaluator group (Hölmer & Louhevaara 2003). Evaluation was done by using the EFQM Excellence Model (Kaplan and Norton 1996). Customer satisfaction was evaluated by interviewing representatives from two large companies and two small- to medium-size companies that participated in the development projects of the CWAP. Customer satisfaction was evaluated as very high. The interviewees named several concrete benefits from the projects, such as learning material and
guidance in protective clothing purchases. Evaluation of the long-term effects and economic effects was suggested by the interviewed customers. (Louhevaara 2002). However, implementation and diffusion of the development results and the effects of the CWAP in the long run were not evaluated or published.
4 Objectives of the study

4.1 General objective and theoretical framework

The overall purpose of this study was to improve the occupational safety and health, quality and productivity of cold work. This thesis presents the development, implementation and evaluation of a general, systematic model and methods for managing cold-related health and safety risks as a part of a company’s OSH or SHEQ management system and practices.

The theoretical framework of this study combines various theories, models and practices. The research knowledge about cold work and cold-related health and safety risks is combined in the general risk assessment and management models and SHEQ systems (Article I). The models and good practices of research-assisted development and ergonomics development work are utilized in the application and development work in the case organizations and their actual workplaces (Articles II and IV). Theories of productivity and cost theories are utilized in analyzing the costs of the cold work and cold risk management activities (Article III). Finally, evaluation knowledge produced in the implementation and effectiveness studies is utilized in evaluating the implementation process, long-term effects and affecting factors (Article IV). The PDCA is used as a chronological framework in this study to bind together these various aspects. The theoretical framework of the thesis is presented in Figure 4.
Fig. 4. Theoretical framework of the thesis.

Developing the Cold risk management model and methods (original article I)
- Cold work environment, cold work
- Cold exposure, effects of cold on human
- Cold-related occupational health and safety risks
- Productivity and quality of the work
- Occupational safety and health (OSH) management systems
- Safety, health, environment and quality (SHEQ) management systems
- Risk assessment and risk management
- Preventive measures against cold
- Continuous improvement

Applying the Cold risk management model and methods practices in companies (original articles II, IV)
- Work environment development, ergonomics development models and processes
- Research-assisted development
- Systems thinking
- Information and training

Evaluating the development and implementation process and long-term effects of cold risk management (original article IV)
- Implementation and dissemination process
- Results and effects
- Helping and hindering factors

Analyzing the cold-related additional personnel costs and profitability of cold risk management (original article III)
- Cost information
- Productivity, cost-efficiency, effectiveness
- Costs and profitability of the OS activities
4.2 Specific aims

The specific aims of this study were to:

1. develop a general, systematic model and methods for managing cold-related health and safety risks as a part of an organization’s OSH management system or SHEQ management system and evaluate their usability in different types of cold outdoor and indoor work (construction work, fish processing industry) and by OSH professionals (Article I).

2. apply the systematic Cold Risk Management Model and methods in cold outdoor work in a case company in the field of construction, gather feedback about the initial develop phase and further develop a company-specific cold risk management toolkit as a part of the company’s SHEQ management system (Article II).

3. evaluate the economic effects of cold work at a construction site and in the construction industry in Finland, and evaluate the profitability of cold risk management activities at a case company’s construction site (Article III).

4. apply the systematic Cold Risk Management Model and methods in cold outdoor work in a case company in the field of maritime administration and services, to make a company-wide implementation plan for the cold risk management activities, and to evaluate the development and implementation process, results, long-term effects and factors influencing the implementation of cold risk management activities in the case company (Article IV).
5 Materials and methods

5.1 Progress of the study

A systematic model for managing cold-related risks and practices was developed to be integrated into an enterprise’s OSH or SHEQ management system. The Cold Risk Management Model and methods were evaluated in cold indoor and outdoor work and by OSH professionals. (Article I.)

The Cold Risk Management Model and practices were applied in two case companies: case company YIT in the construction industry (Article II) and case company FMA in maritime administration and services (Article IV). The studies were part of the national Cold Work Action Program (CWAP), which aimed to transfer scientific knowledge about cold into practice in different types of workplaces. In the fixed-period CWAP, the method development and the research-assisted development work ran at the same time. Furthermore, the personnel of the case companies participated actively in the development work to combine the tacit knowledge with the scientific knowledge in order to produce usable and effective cold risk assessment and management methods and practices.

Cold-related additional personnel costs at a construction site and in the whole construction industry in Finland were evaluated. The profitability of cold risk management in case company YIT was evaluated. (Article III.)

The process of implementing the Cold Risk Management Model and methods and the factors influencing implementation were evaluated in case company FMA (Article IV). The original studies and the progress of the thesis are presented in Figure 5.
Evaluation of the development and implementation process, results and long-term effects in FMA (IV)

Implementation and dissemination of the results by FMA

Development work for cold risk management in the case organization FMA (IV)

Evaluation of the cold-related additional personnel costs in construction industry (III)

Evaluation of the profitability of cold risk management model and methods in the case organization YIT.

Development work for managing cold risks in the case organization YIT’s SHEQ system and practices (II)

Application and feedback of the cold risk management model and methods in research-assisted development work

Method development in CWAP projects. “Risk assessment and management of cold related hazards in Arctic Workplaces” project 1999 - 2001

Development and evaluation of the usability of a systematic Cold risk management model (I)


Production of learning & guidance material:
- Guide book for cold work (Fi, Swe, No)
- Method handbook for cold work (Fi)
- Industry-specific cold guide booklets

Doctoral thesis of T. Riskko

ISO 15743:2008

Fig. 5. Original studies and the progress of the thesis.
5.2 Development of a general Cold Risk Management Model and cold risk management methods (I)

5.2.1 Developing the model and methods

Original article I presents the development of a general model for managing cold-related occupational health and safety risks at workplaces. The underlying principles were derived from existing OSH legislation, standards and guidelines. The Cold Risk Management Model was planned to be integrated in a company’s OSH management system OHSAS 18001 or a combined SHEQ management system, which is based on a combination of occupational health and safety, environment and quality management standards and specifications, such as ISO 9001, ISO 14001 and OHSAS 18001 (ISO 9001, ISO 14001, OHSAS 18001).

The Cold Risk Management Model was accompanied by cold risk management methods. The methods were developed to be used as tools for planning cold risk management activities and for selecting the most appropriate concrete measures in individual workplaces. The methods were developed by combining the essential elements of existing standards and guidelines, research-based knowledge and tacit knowledge.

The model and methods were developed during the CWAP, hand in hand with research-assisted ergonomics development work in the case companies. Feedback from the companies was utilized immediately to further refine the methods.

5.2.2 Evaluating the usability of the Cold Risk Management Model and methods in workplaces

The usability of the model in practice was tested and evaluated 1) in the construction industry in northern Finland (cold outdoor work) and 2) in the fish processing industry in northern Norway (cold indoor work). The usability of the cold work plan and its cold risk management methods was evaluated in association with other methods developed during the CWAP. These were the cold risk assessment checklist, recommendations for information and training of the personnel and occupational health care practices for cold work. (Risk assessment and management of cold related hazards in Arctic Workplaces: Network of Scientific institutes improving practical working activities 2001.)

Construction work is project type outdoor work at construction sites. The work tasks, physical load, work environment and weather conditions change
continuously. The number of employees working at the site also varies during the building project. The Cold Risk Management Model and methods were tested at two construction sites of a large nationwide construction company, YIT Construction (YIT). The construction sites were located in Kemi and Tornio in Lapland, Finland. At the time of the study, the company employed altogether roughly 1000 persons in Finland. The company employed 25 officials and 60–70 workers at its construction sites in northern Finland. (Risk assessment and management of cold related hazards in Arctic Workplaces: Network of Scientific institutes improving practical working activities 2001.)

The usability of the Cold Risk Management Model and methods was evaluated in association with other methods developed during the CWAP. These were the cold risk assessment checklist, recommendations for information and training of the personnel and occupational health care practices for cold work. Preceding the activities, a short training course on the purpose and principles of the methods was given to the key persons of the construction company. These key persons were the occupational safety delegates, construction site foremen and occupational health care personnel. The activities were planned by three key persons for two different construction sites. Simultaneously, cold risks were assessed by using the cold risk assessment checklist. Cold risk management activities at the two specific construction sites were systematic planned using the structured Cold risk management plan form. The usability of the methods was assessed in feedback discussions. (Risk assessment and management of cold related hazards in Arctic Workplaces: Network of Scientific institutes improving practical working activities 2001.)

The usability of the Cold Risk Management Model and methods was evaluated in two fish processing companies in Båtsfjord, in northern Norway. Altogether, 52 employees from the two pilot companies participated in the evaluation. The individual workers’ tasks in fish processing work are monotonous and repetitive. The ambient temperature is cool and the environmental conditions are rather constant. However, temperature gradient, air movements, frozen products and moisture increase the adverse effects of cold. Cold risks at the workplaces were assessed by using the cold risk assessment checklist (Mäkinen et al. 2002). The cold-related health aspects of the workers were assessed with a personal health check questionnaire (Hassi et al. 2003). Cold-related problems were verified by means of temperature measurements. Corrective actions were planned systematically using the cold work plan. The main emphasis in the process-type work was laid on cold protective clothing and personnel training.
Feedback was gathered in discussions with the managers and the workers. (Risk assessment and management of cold related hazards in Arctic Workplaces: Network of Scientific institutes improving practical working activities 2001.)

5.2.3 Evaluation of the model and methods by OS and OHC professionals

The produced model and methods were further evaluated by an expert group consisting of occupational safety (OS) and occupational health care (OHC) professionals, trainers, researchers and postgraduate students (N = 33), who attended the 3rd International Course on Performance in Cold Environments organized by The Nordic Institute of Advanced Training in Occupational Health and other Work Life Matters (NIVA) in March 2002. The persons in the evaluation group represented various types of cold outdoor and indoor industries, such as food processing, airport personnel’s work, fishing, maintenance work in the offshore oil industry and work in cold storage. The persons were not familiar with the Cold Risk Management Model and methods in advance.

The developed general model, the cold risk management plan and methods were first presented to the expert group. In the same way the cold risk assessment checklist (Mäkinen et al. 2002) and the OHC activities for cold work (Hassi et al. 2003) were presented to the expert group. The developed model and methods were then test-used and evaluated in five working groups, each of which concentrated on one specific type of cold outdoor or indoor work: 1) food processing, 2) airport personnel’s work, 3) fishing, 4) maintenance work in the offshore oil industry and 5) work in cold storage. The working group leaders came from these industries, and they were able to describe the work to the entire working group. The health and safety risks of the work were evaluated using the cold risk assessment checklist. The group then planned protective measures using the structured cold work plan. The usability of the methods was then evaluated in a feedback discussion.

5.3 Cold risk management in a construction company (II)

5.3.1 Case company YIT

The Cold Risk Management Model and methods were applied in practice in construction work at two construction sites of YIT Construction Ltd (YIT). These
are called pilot sites in this study. The study covers the assessment of cold-related risks at the pilot sites, application of the Cold Risk Management Model and cold work plan at the pilot sites, development of the company-specific tools and information material for cold risk management, concrete development activities at the workplaces, the personnel training and information campaign and the development and piloting of supporting OHC activities.

Two construction sites of YIT’s Northern Finland Unit in Oulu served as pilot sites for the development project: pilot site 1 (“Joutsenkaari” 1998–1999) and pilot site 2 (“Oravanpesä” 1999–2000). The foremen and OS delegates (N=6) of the pilot sites as well as the company’s quality and OSH management personnel participated in the development process. The two pilot sites employed an average of 20 persons per construction site during the development phase. In addition, several subcontractors worked at the pilot sites during the process. A questionnaire survey concerning cold work was returned by altogether 46 employees at both pilot sites. At the pilot sites, 39 employees participated in the cold risk assessments. Key persons from the local external OHC organization were involved in the process. During the development project, approximately 60 persons in all worked at the pilot sites, some of which were employed in various short-term subcontracting work.

YIT Construction Ltd is a part of the larger YIT Corporation. At the time of the development process, the entire YIT Corporation was developing an integrated SHEQ management system to replace the previous separate systems. The British standard BS 8800 served as a reference for the OSH management section. (BS 8800). BS 8800 is analogous to OHSAS 18001 in its basic principles.

5.3.2 Development process and methods

Cold-related health and safety risks as well as present cold risk management practices were identified by interviewing the employer’s representative (N=1) and with a questionnaire study among the workers (N=46) (appendix 2, Risikko et al. 2000a). The risks in different tasks in various ambient temperatures (Ta<-10°C, -10°C<Ta<0, Ta>0°C) were identified in workplace assessments at the pilot site 1 in January–April 1999 (N=39). International thermal standards were utilized for the assessments (Mäkinen & Hassi 2002). Air temperature and wind velocity were measured (Silva Windwatch). Individual health-based, cold-related risk factors
were further assessed by means of health questionnaires and health checks by OHC professionals from the CWAP (Hassi et al. 2003).

The practical cold risk management methods were piloted at pilot site 1 in order to find the most suitable methods for the case company, to achieve concrete improvements and to commit the personnel in the Cold Risk Management Model and methods to be established. The foremen and safety delegates were trained to be able to recognize and manage cold risks in construction work and to guide and train their workers. The workers were trained through an information campaign at pilot site 1. Further written instruction and guidance material was provided. Clothing trials were connected with the information sessions. Immediate feedback on the concrete development activities was gathered by means of a questionnaire (N=9) and a feedback discussion with the workers at the pilot site. (Risikko et al. 2000a.)

The Cold Risk Management Model and methods were integrated in the company’s SHEQ management system. After the preliminary concrete cold risk management activities at pilot site 1, the Cold Risk Management Model and methods were integrated in the SHEQ system, the OSH and OHC practices of YIT Construction Ltd and also in the SHEQ system of the whole YIT Corporation. The integration was planned in the workshops together with the personnel and quality management, the OSH management and OHC management of the whole YIT Corporation, the management, foremen and OS delegates of the northern Finland unit of YIT Construction Ltd, the representatives of the local external OHC organization and the experts from the CWAP. On the practical level, the aim was to integrate the cold risk management activities seamlessly into the general OSH practices at the construction sites and into routine OHC practices.

Pilot site 2, called “Oravanpesä”, served as a test field for the refined Cold Risk Management Model and methods. In the starting phase of pilot site 2, the foreman and the safety delegate of the workers planned the cold risk management actions for the pilot site using the cold risk management plan form, which was now available in the company’s OSH management data system. They planned the following concrete cold risk management actions for pilot site 2: scheduling and implementation of the cold risk assessment at the pilot site, organizational cold risk management activities (work methods, need for extra personnel, construction site layout, etc.), technical cold protection actions (wind shelters, spot heaters etc.), procurement of protective clothing and PPDs, information and training to be given to the workers, and needed support activities from the external OHC experts. The schedule of the activities was planned and coordinators were named.
The cold risk management activities were then carried out according to the plan. (Risikko et al. 2000a.)

5.4 Analyzing the economic effects of cold work and cold risk management (III)

The additional personnel costs caused by cold in construction work were specifically measured at three YIT construction sites in 1999–2000: construction site I (March 1999–December 1999), construction site II (September 1999–May 2000) and construction site III (November 1999–August 2000). The apartment buildings to be built at these construction sites were identical, and thus the work phases of the construction sites were identical. An average of 20 persons were employed at each construction site. In the study the following costs were measured: 1) the cold-related additional personnel costs of the construction work in total, and particularly 2) the additional personnel costs of bricklaying work.

The cold-related operational activity chains in the construction work were first identified by using the literature, a questionnaire among the workers (N=9) and a questionnaire and interviews among the foremen (N=7) of YIT. The data were elaborated in the construction site meetings and by the management and YIT’s OHC personnel. The gathered data were classified into factors related to the environment, cooling of the human body and existing norms and regulations.

The effect of cold conditions on productivity and work efficiency was then evaluated by measuring the additional personnel costs due to the cold conditions at construction sites II and III compared with construction site I, where the foundations and frame were built during the warm season. The following criteria were used: 1) the required work hours per built m³, 2) the price of the bricklaying work and 3) the income of the bricklayer. The construction sites were identical in terms of their work phases and construction volume. The sites were started in March 1999, September 1999 and November 1999.

The additional personnel costs caused by cold in the whole Finnish construction industry were then evaluated by using the data gathered from the three YIT construction sites and the following statistics and data: construction volume in different parts of Finland from the Confederation of Finnish Construction Industries RT 1999 (Construction volume in different parts of Finland 1991), the number of employees in the construction industry from Statistics Finland (SVT 1999) and weather data from the Finnish Meteorological Institute. The proportion of outdoor work at a construction site was estimated by
an expert group consisting of YIT construction professionals and experts from the CWAP.

The costs and savings of the cold risk management activities were calculated for a construction site identical to construction sites I, II and III. The number of employees was 20 at the site, and the frame of the building was erected in the winter time. The duration of the cold work period at the construction site was 5 months. The costs were calculated for planning the activities, assessing the cold risks, conducting the organizational and technical cold risk prevention measures, procurement of protective clothing and PPDs and organizing a training campaign for the workers. The achieved savings were estimated by calculating the savings that could be measured directly at the construction site, such as saved work hours or reduced material loss. The prices of the work, protective clothing, material, etc., were based on the real prices from construction site I.

5.5 Evaluating the implementation process and long-term effects of cold risk management at the FMA (IV)

The Finnish Maritime Administration (FMA) produces services for the maritime industry. A development project for improving health and safety in cold work was carried out at the FMA in 1999–2001. The implementation and effects of the development project at the FMA were assessed in an evaluation study. The evaluation study was carried out 3 years after the end of the initial development phase in 2003. The development, implementation and evaluation processes are presented in Figure 6.
Fig. 6. Implementation of cold risk management in occupational safety and health practices at the Finnish Maritime Administration. The development, implementation and evaluation process. (IV, published by permission of the The Central Institute for Labour Protection – National Research Institute, Poland).

At the time of the development project, the organization was divided into four geographical divisions. On the other hand, several occupational sectors were identified on the basis of the various tasks of the FMA, such as channel maintenance, piloting and icebreaking. The northernmost Gulf of Bothnia Division (GBD) served as the pilot group in the development project. The central OSH unit of the FMA coordinated and lead the OSH and OHC activities of the
whole organization. Practices such as workplace risk assessment were carried out in each division by their own occupational safety (OS) personnel. The personnel’s OHC services were organized in cooperation with local external OHC units.

The initial development project for improving occupational health and safety in cold work was carried out at the FMA in 1999–2001 in cooperation with the CWAP. The Gulf of Bothnia Division (GBD), which is geographically the northernmost division of the FMA, served as a pilot division in the development project. Prior to the development stage, the environmental risk factors of cold work and perceived cold-related health and safety effects among the FMA’s personnel were identified by means of a questionnaire survey. The number of respondents was 631 (65% of the sent questionnaires). The number and characteristics of the respondents are presented in Table 2. (Juopperi et al. 2000). The identified cold-related problems, tasks and work environment were then observed and assessed in various workstations. The development actions were planned by using the logic of the Cold Risk Management Model (Article 1). A training campaign was organized, accompanied by immediate cold protection measures and clothing trials. The key results and implementation tools of the development project were: 1) a company-specific model and practices for assessing and managing cold risks at the FMA’s divisions and workstations, 2) immediate improvements in the pilot division (GBD) and recommendations for further development, 3) a training campaign in the GBD and a Cold Work Guide booklet, 4) a model and practices for cold-related OHC activities at the FMA, and 5) a plan and tools for implementation for sustainable results and organization-wide dissemination.

After the initial development project, a scheduled plan for implementation was made for implementation and dissemination activities at the FMA. The implementation plan included: 1) recommendations for implementation activities in the FMA’s central OSH unit, for coordinators and for establishing a specific training team (Cold Team), 2) recommendations for implementation activities in the divisions, for example procurement of protective clothing, 3) a plan for an organization-wide training campaign, accompanied by training and information material, 4) a plan for cold-related OHC practices in the FMA’s OHC program, including instructions and training for external local OHC units. The organization-wide implementation process was scheduled to take place during the two years after the development process.

An evaluation study was carried out three years after the initial development project. In the study, the development outcomes, the changes in cold risk
management activities, the factors that had influenced the implementation and the changes in the perceived cold-related risks and effects were evaluated. The process, the outputs, the effects and the influential factors were analyzed and interpreted against four interest levels during the development and implementation phases: 1) SHEQ management and practices (Organization level), 2) concrete development actions undertaken at the workstations (Action level), 3) the personnel’s awareness and knowledge about cold work (Awareness level), and 4) supporting expert activities, such as occupational health care practices (Support level). The data were collected by using two methods: a questionnaire (appendix 3) and interviews (appendix 4). The PDCA cycle (Deming 1986) was used as a chronological framework for the development and implementation activities. The interest levels and the chronological framework formed a matrix that was used in the synthesis of the results. Multiple sources of evidence were used to form a comprehensive picture of the process, outputs and influential factors.

The study population targeted by the questionnaire study in 2003 was selected on the basis of the initial development project. The number of FMA employees working outdoors in 2003 was roughly the same as in 2000 (Table 2). The number of respondents was 314 (31% of the sent questionnaires). The questionnaire was not re-sent to the study group, which may explain the lower number of respondents compared with the questionnaire in 2000. However, the characteristics of the respondents were similar in the questionnaire surveys in 2000 and 2003, and the study population can thus be considered as the same (Table 2). The percentage of GBD respondents among all respondents (16–17% in both surveys) was also equal to the percentage of GBD employees among all FMA employees.

The questionnaire (appendix 3) consisted of structured, quantitative questions and open questions. It was targeted to find out changes in cold risk management practices at the workplaces and changes in perceived environmental risk factors, symptoms and adverse effects caused by cold. The statistical methods used were cross tabulations of variables and Pearson chi square test ($\chi^2$ test) and Fisher’s exact test (2-sided) statistics for independence. Qualitative content analysis was used to analyze the open questions. The results were compared with the results of a similar cold questionnaire conducted in 2000 (Juopperi et al. 2000).
Table 2. Characteristics of the respondents to the cold work questionnaire at the Finnish Maritime Administration in 1999 (Juopperi et al. 2000) and 2003 (Article IV).

<table>
<thead>
<tr>
<th>Personnel groups (% of respondents)</th>
<th>Questionnaire* in 2003</th>
<th>Questionnaire** in 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age</td>
<td>48.4 years</td>
<td>46.8 years</td>
</tr>
<tr>
<td>N = 314</td>
<td>N = 631</td>
<td></td>
</tr>
<tr>
<td>Personnel groups (% of respondents)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilots</td>
<td>19</td>
<td>23</td>
</tr>
<tr>
<td>Pilot cutter drivers</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Channel maintenance personnel</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Vessel personnel</td>
<td>34</td>
<td>26</td>
</tr>
<tr>
<td>Other (mostly working onshore)</td>
<td>24</td>
<td>31</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Personnel of the GBD</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Physical activity at work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light physical work</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>Intermediate physical work</td>
<td>31</td>
<td>32</td>
</tr>
<tr>
<td>Heavy or very heavy physical work</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Office work</td>
<td>21</td>
<td>23</td>
</tr>
</tbody>
</table>

* The questionnaire was sent to the personnel (N = 1024), not re-sent
** The questionnaire was sent to the personnel (N = 975) and re-sent

In addition to the questionnaire, 20 persons were interviewed. The interviewees represented various maritime divisions and professions. There were 9 persons from the GBD and 11 persons from other divisions. All 20 interviewees had responded to the cold questionnaires in both 2000 and 2003. Nine GBD interviewees and 6 interviewees from other divisions had participating in the training, field studies or trials of the initial development project. Two interviewees had been actively involved in the development activities. Five persons had not participated in the development activities. The interviews were carried out to evaluate the development outputs, the implementation practices and their effectiveness and the factors that had influenced the implementation process. A semi-structured interview form was sent beforehand to the interviewees (Appendix 4). The answers were then complemented in a phone interview carried out by the occupational health expert of the FMA. The duration of each phone interview was 10–20 minutes. The data were analyzed using qualitative content analysis.
6 Results

6.1 A systematic general model for managing cold risks (I)

6.1.1 Cold Risk Management Model

In order to ensure the implementation and continuance of the activities, cold risk management should be integrated into the company’s SHEQ management systems and practices. The activities follow the norms given by general OSH laws, trade agreements and industry-specific safety regulations. The effects of cold risk prevention actions should be reviewed and analyzed as a part of OSH activities at the company management level, following the principles of continuous improvement.

The actual cold risk assessment and cold protection actions are planned and carried out at each individual workplace, taking work-specific requirements into consideration. The key persons should have all the necessary supporting information for planning and carrying out the activities. The whole personnel in the workplace should be informed about the activities and should also receive necessary training.

A general Cold Risk Management Model was developed for this purpose (Figure 7). The model presents the structure for integrating cold risk management principles and activities into a company’s SHEQ management system, concrete cold risk management measures in individual workplaces, personnel training practices and occupational health care activities. The Cold Risk Management Model was planned to be compatible with the OSH management system OHSAS 18001. The Cold Risk Management Model was published in short form in original study I and further elaborated with the specific activities at each activity level. The Cold Risk Management Model was later included as an essential part of ISO 15743 (ISO 15743).

6.1.2 Cold risk management methods

Concrete cold risk management activities should be planned in written form, either as a part of the general occupational safety plan of an individual workplace or as a separate plan. A cold risk management plan was developed for this purpose (Figure 8).
The aim of the planning is to take various cold-related aspects systematically into consideration already in the planning stage of the work, especially in project type work, and to ensure successful timing of implementation of various preventive activities. The cold risk management plan, accompanied by practical guidelines and examples of alternative preventive measures, were published in Article I, in the guidebooks and instructions for cold work (Hassi et al. 2002, Risikko et al. 2004), and finally, as Annex C in ISO 1574 (ISO 15743). Different cold risk management methods are introduced briefly in the following chapters.
Fig. 7. Cold Risk Management Model and methods related to it (modified from Article I, with permission of International Association of Circumpolar Health Publishers).
**COLD RISK MANAGEMENT PLAN FOR THE WORKPLACE**

<table>
<thead>
<tr>
<th>Workplace:</th>
<th></th>
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<tbody>
<tr>
<td>Plan prepared by:</td>
<td></td>
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<tr>
<td>Coordinators:</td>
<td>Full name &amp; initials:</td>
</tr>
<tr>
<td>Foreman of the workplace</td>
<td></td>
</tr>
<tr>
<td>Occupational safety coordinator</td>
<td></td>
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<tr>
<td>Occupational safety delegate</td>
<td></td>
</tr>
<tr>
<td>Etc.</td>
<td></td>
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<tr>
<td>Who supervises the activities?</td>
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</table>

**COLD RISK ASSESSMENT**

Fill in the procedure for cold risk assessment at this particular workplace

<table>
<thead>
<tr>
<th>coord.</th>
<th>date</th>
<th>superv.</th>
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**PREVENTIVE MEASURES AGAINST COLD RISKS**

Fill in the needed cold risk prevention measures

<table>
<thead>
<tr>
<th></th>
<th>coord.</th>
<th>date</th>
<th>superv.</th>
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<tbody>
<tr>
<td>1. Organizational preventive measures, planning of the work</td>
<td>Measures to be conducted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In the planning phase of the project</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before every work shift</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>During the actual work shift</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Technical preventive measures</td>
<td>Measures to be conducted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tools, equipment, machinery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slippery surfaces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking on stairs, work at heights</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Protective clothing &amp; PPE</td>
<td>Measures to be conducted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clothing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handwear</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Footwear</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head and face protection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Information and training</td>
<td>Measures to be conducted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Occupational health care</td>
<td>Measures to be conducted</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 8. Cold risk management plan for a workplace (modified from Article I, with permission of International Association of Circumpolar Health Publishers).
Together with the development of the cold risk management plan, the usability of the present ISO thermal and risk assessment standards was evaluated (Mäkinen et al. 2002). Based on this evaluation, it was recognized that new practical methods for identifying and assessing cold hazards are needed. Therefore, a cold risk assessment checklist for workplaces was produced and tested by end users (Mäkinen et al. 2002). The method is based on observation and does not require comprehensive training or knowledge in e.g., ergonomics. Furthermore, for a person at the workplace who is well aware of the contents of the work, observation does not require a much time and is inexpensive for the company. Risk assessment should be conducted whenever there is a change in work conditions or in the contents of the work. Cold risks should be identified and analyzed to an extent required to solve any problems. If the personnel of the workplace cannot solve the problems, more complicated risk assessment and management methods are applied. Cold risk assessment can be done together with general risk assessment or a regular occupational safety check at the workplace.

In the cold risk management plan, organizational cold protective measures refer to the planning and organizing of the work. The main purposes of the measures are to control the duration and intensity of cold exposure and to provide sufficient time, measures and space for recovery. For example, in outdoor work extra manpower can be provided for efficient and safe work-rest regimens. The work load should also be kept at a rather constant level to avoid excessive sweating and consequent evaporative cooling. Organizational cold risk management measures also require an appropriate communication system. In severe cold conditions, a “buddy monitoring system” may be introduced for observing cold-related subjective reactions over time.

Technical preventive measures are conducted to reduce radiation, convective and conductive heat loss from the worker. For example, a wind shelter reduces both convective heat loss through clothing and the risk of frostbite on bare skin. In indoor work, temperature gradients should be reduced and heat conduction to cold surfaces and products should be prevented or reduced. A list of technical cold risk management methods includes, for example, selection of tools and machinery, reduction of slippery areas, providing sufficient lighting, isolating the work area from cold surfaces.

Protective clothing and PPE are chosen and used on the basis of the workplace risk assessment. The need for thermal insulation can be roughly determined by using the IREQ index (ISO 11079), for example. Guidelines on the required protective and functional properties of clothing that protects against the
cold and foul weather are given in the European standards (EN 342, EN 343). In addition, the extremities should be protected well. Attention should also be paid towards the compatibility of protective clothing with PPDs. Guidelines for selecting multilayer clothing, cold protective clothing, hand wear, headwear, footwear, face protection and PPE are given in the guidebooks and guidelines for cold work (Hassi et al. 2002, Risikko et al. 2004).

In order to ensure successful implementation of cold risk management practices, workers, foremen and occupational safety persons need to be informed and trained to recognize cold risks and to know the ways to prevent or reduce them. Training and information, as well as instruction and guidance material, should be practical and industry-specific. Industry-specific cold guide booklets were produced and delivered in the target companies of the development projects (Risikko et al. 2000b, Risikko et al. 2001).

Occupational health care (OHC) activities for cold work should be planned on the basis of both a cold-related risk assessment at the workplace and individual cold-related health assessments. To identify cold-related health problems, a specific health check for cold work was developed (Hassi et al. 2003).

6.1.3 Usability of the model and methods

The usability of the Cold Risk Management Model and its tools was tested and evaluated at workplaces in the construction industry (cold outdoor work) and the fish processing industry (cold indoor work). The usability of the model and methods was also evaluated by a group of OSH professionals who participated in an international training course in cold work.

According to the feedback from the construction sites’ foremen and safety delegates, planning cold risk management using the cold risk management plan took 45–90 minutes, depending on the construction site. According to the respondents, the provided instructions and material required some getting into, but using the methods was considered meaningful in the long run.

According to the feedback from the fish processing factories, the cold risk assessment checklists, the assessed thermal sensations and the temperature measurements identified the same cold-related problems. After planning and actually carrying out the cold risk management activities, the factory management and workers confirmed that they had become more aware of their responsibility and possibilities of improving the comfort and safety of cold work. It was also
demonstrated that with a systematic approach, development and training activities could be performed for a group of workers without a common language.

The group of OSH professionals considered the cold risk management plan and methods useful and usable. Three major points were pointed out. First, the developed methods were easy to use after a short introduction. Second, the persons who were familiar with the profession in question could easily identify industry-specific and work-specific cold risks by using the checklist and were able to plan protective measures. Third, the continuum between the checklist and the cold work plan worked well. Although, while the immediate preventive measures were recorded already when the cold risks were identified by using the checklist, the risk assessment and risk management methods were partly overlapping.

6.2 Applying the Cold Risk Management Model in the case company YIT (II)

6.2.1 Cold risks in construction work

Based on initial interviews of the foremen and the workers’ OS delegates, cold was not taken into account sufficiently in OSH or OHC activities or in the procedure of informing and training a new employee. Neither the foremen nor the external OHC unit were aware of possible cold-related sicknesses or injuries among the employees. The company provided the workers protective clothing, which was recommended in the trade agreement. In addition, various kinds of protective gloves were provided. According to the initial cold questionnaire (N = 46) the workers had experienced cold-related disease symptoms, cold injuries, discomfort (73% of the respondents), decrease in work performance (52%), and reduced work motivation (78%). The most problematic ambient factors were wind, cold materials and wet conditions. An increased risk of occupational accidents due to cold conditions was perceived by 76% of the respondents. The hands and feet were most susceptible to cold-related detrimental effects. The overall thermal insulation of the clothing was sufficient, but the clothing did not protect sufficiently against rain, wet snow and wind. According to the health surveys, one third of the workers had cold-induced or cold-related symptoms, mostly respiratory symptoms and symptoms in the body extremities. The workplace assessments at pilot site 1 showed a risk of extremity and contact cooling in many work phases and a risk of whole body cooling during the cold
season in tasks involving low heat production. A summary of the cold-related risks is presented in Table 3.

Table 3. Cold-related OSH risks assessed in construction work at pilot site 1.

<table>
<thead>
<tr>
<th>Cold-related risks and their main reasons</th>
<th>Work phases and tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discomfort</td>
<td>Boarding, measuring, barbending</td>
</tr>
<tr>
<td>light work</td>
<td>Boarding, measuring, barbending, element</td>
</tr>
<tr>
<td>insufficient protection of the extremities</td>
<td>installation</td>
</tr>
<tr>
<td>Whole body cooling</td>
<td>Boarding, measuring, barbending, element</td>
</tr>
<tr>
<td>light work</td>
<td>installation</td>
</tr>
<tr>
<td>Extremity cooling</td>
<td>Boarding, measuring, barbending</td>
</tr>
<tr>
<td>working barehanded</td>
<td>Boarding, measuring, barbending</td>
</tr>
<tr>
<td>wet and cold materials</td>
<td>Boarding, measuring, barbending</td>
</tr>
<tr>
<td>Contact cooling</td>
<td>Boarding, barbending, miscellaneous assisting work</td>
</tr>
<tr>
<td>working barehanded</td>
<td>Boarding, barbending, miscellaneous assisting work</td>
</tr>
<tr>
<td>contacts with metal</td>
<td>Boarding, barbending, miscellaneous assisting work</td>
</tr>
<tr>
<td>Combined effect of cold and vibration</td>
<td>Boarding, element installation, concrete</td>
</tr>
<tr>
<td>exposure to vibrating tools and machinery</td>
<td>casting, miscellaneous assisting work</td>
</tr>
<tr>
<td>Increased risk of occupational accidents</td>
<td>Element installation, boarding, barbending, measuring, other tasks</td>
</tr>
<tr>
<td>slippery surfaces, darkness</td>
<td>Element installation, boarding, barbending, measuring, other tasks</td>
</tr>
</tbody>
</table>

6.2.2 Immediate development results at the pilot sites

The research-assisted development work at the pilot sites ran hand in hand with the development of a company-specific model for cold risk assessment and management and development of the general Cold Risk Management Model (Article I). The methods were tested at the pilot sites and feedback was utilized immediately to further refine the methods.

At pilot site 1, short information sessions about cold work and cold protection methods were held for the workers. The duration of the practical information sessions was 15–30 min. A cold work guide, “Rati-riti-ralla”, was delivered to everybody (Mäkinen et al. 1999). The information sessions were accompanied by clothing trials, which were planned on the basis of present state analysis. The workers indicated in the feedback questionnaire and discussion that they had received new knowledge about the effects of cold and cold protection (Table 4). The workers also reported that the concept of multilayer clothing helped in maintaining thermal comfort during changing work situations and reduced bulkiness of the clothing, and that especially protection of the hands against cold had improved.
Table 4. Construction workers’ feedback about the information sessions at pilot site 1 (% of the respondents).

<table>
<thead>
<tr>
<th>A lot of new information (%)</th>
<th>Some new information (%)</th>
<th>No new information (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Underwear as a part of multilayer clothing</td>
<td>36</td>
<td>64</td>
</tr>
<tr>
<td>2. Mid-layer as a part of multilayer clothing</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>3. Water-repellency of outer garments</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>4. Effects of wind and protection against it</td>
<td>36</td>
<td>64</td>
</tr>
<tr>
<td>5. Effects of cold on physical performance</td>
<td>27</td>
<td>64</td>
</tr>
<tr>
<td>6. Effects of cold on health</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>7. Decreasing contact cooling</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>8. Cold protection of the feet</td>
<td>27</td>
<td>45</td>
</tr>
<tr>
<td>9. Clothing as personal protective equipment</td>
<td>18</td>
<td>73</td>
</tr>
<tr>
<td>10. Rätirill, Cold guide for Finns</td>
<td>27</td>
<td>73</td>
</tr>
</tbody>
</table>

At pilot site 2 ("Oravanpesä"), the Cold Risk Management Model and methods were applied by the pilot site’s personnel themselves. Cold risks were assessed by using the checklist (Mäkinen et al. 2002), preventive measures against cold risks were planned by using the cold risk management plan, concrete measures were taken, a Construction Worker's Guide to the Cold was delivered to everyone, and cold-related health care activities were undertaken by the local external OHC unit. Substitute tasks were planned beforehand for the coldest winter periods, and weather shelters were located in the construction site plan. The barbending table was covered with a wind shelter, which protected against wind, rain and snow. The barbending working area was improved by efficient lighting and a platform to isolate the work area from the ground. Weather shielding techniques were also tested in bricklaying work. The weather shelter system was adopted as a routine in all of YIT’s later construction sites in the Oulu region. An appropriate set of cold protective clothing, thermal underwear, gloves, protective boots and other PPE was selected for the workers based on the feedback from pilot site 1. Information about cold work was given by the OHC personnel. According to the feedback discussions with the foremen and the workers’ safety delegate, the methods were easy to use.
6.2.3 Cold Risk Management Model and methods in the case company’s SHEQ management system and practices

A company-specific procedure and methods were created for assessing and managing cold-related OSH risks in construction work (Figure 9). Cold risk management was also integrated in the SHEQ system, not only in YIT Construction Ltd, but also in the whole YIT Corporation. Cold was named as one of the physical risk factors to be managed in the company’s OSH policy. The corporation’s guidelines for external OHC units contained instructions for identifying and treating cold-related health problems of the workers.

A set of methods was established as a practical tool for the company’s OS personnel, construction site foremen and the worker’s OS delegates. The layout of the cold risk management plan (Figure 8) was modified to comply with the company’s other quality and safety documents. The cold risk management plan was made available in the company’s internal electronic information system. The cold risk plan was accompanied by a company-specific information package, which was produced in electronic and article form. The information package included instructions for planning cold risk management activities, a cold risk assessment checklist with instructions for use, material for training sessions and practical information about cold protection measures, such as suppliers of protective clothing. A nine-page booklet Construction Worker’s Guide to the Cold (Risikko et al. 2000b) was published as training material for everybody working at the construction site. It contained information about cold risks and practical guidelines for multilayer clothing. Information material was also produced for the OHC care personnel. According to the case company’s instructions, a cold risk management plan should be compiled for every construction site where there is cold work. In other words, when the foundations of a building are built or the building frame is erected during the cold season. The construction site’s cold risk management plan includes cold risk assessment practices, work planning, technical cold protective measures, procurement of protective clothing and PPEs, information and training practices and guidance material to be provided. The activities are scheduled and coordinators named in the plan.
Fig. 9. A model for managing cold-related risks in the construction industry (translated from Article II, with permission of the Finnish Institute of Occupational Health).
6.3 Economic effects of cold work and cold risk management (III)

6.3.1 Additional personnel costs caused by cold

Effects of cold on productivity. The effect of cold conditions on productivity was evaluated by measuring additional personnel costs due to cold work at three identical construction sites. The criteria used were 1) the required work hours per built m³, 2) the price of bricklaying work and 3) the income of the bricklayer.

The number of work hours spent per cubic meter varied in the three buildings under comparison, depending on the time when the construction work was started. The required work hours were 1.97h/m³ in building I (March–November 1999), 1.86h/m³ in building II (September 1999–May 2000), and 2.60h/m³ in building III (November 1999–August 2000). In building III, the foundation and framework were totally built during the season when the ground was frozen. This construction phase took about four months at the pilot sites. The total construction time of building III was 32% longer compared with the total construction time of building I. The total construction time of building II was 9% lower than of building I, which may have been caused by a learning effect of the construction team or by a partly different construction team.

Identical bricklaying work was done in different seasons at the three identical pilot construction sites. Calculations show that bricklaying work was 10% more expensive in November-January and 27% more expensive in February-April than in the summer, in May-September. Since a bricklayer’s salary is based on built square meters, the salary was 4% lower in November-January and 16% lower in February–April than in the summer period. The calculations are based solely on effective working hours, excluding, for example, sick leaves (Figure 10).

Besides the effects on productivity, cold-related additional personnel costs are caused by sick leaves, occupational accidents, interruption of work caused by weather conditions, quality problems, overwork, need for additional personnel, need for external work and services and early retirement. The effects and volume of these factors could not be measured in this short-term follow-up period, and they are not included in the cost analysis.
Additional personnel costs caused by cold in the whole Finnish construction industry. According to the calculations, cold conditions cause almost €50 million in additional personnel costs per year in the construction industry. This is 3% of the total salary costs of the construction industry (Table 5). The volume of construction work during the cold season has been estimated by using the following data: The volume and the number of employees in the construction industry in different parts of Finland (SVT 1999) and the duration of the thermal winter in different parts of Finland (data from the Finnish Meteorological Institute). The share of cold work and its additional price were estimated using the following data: According to the construction project manager and the site foremen of YIT Construction Ltd, 20% of the construction work is conducted outdoors during the cold season. In this study, bricklaying work was 10–27% more expensive in the cold season compared with the price in the warm season. The average additional salary costs caused by cold and winter were thus estimated to be 20% of the hourly wage.
Table 5. Additional personnel costs caused by cold in the Finnish construction industry.

<table>
<thead>
<tr>
<th></th>
<th>North Finland</th>
<th>Middle Finland</th>
<th>South Finland</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work years</td>
<td>12341</td>
<td>23121</td>
<td>62548</td>
<td>98010</td>
</tr>
<tr>
<td>Number of winter days / work year (daily mean temperature &lt;0°C)</td>
<td>160</td>
<td>120</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Work years done in the cold season</td>
<td>5485</td>
<td>7707</td>
<td>17374</td>
<td></td>
</tr>
<tr>
<td>Outdoor work in the cold season (% of the total work, estimate)</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Outdoor work years in the cold season</td>
<td>1097</td>
<td>1541</td>
<td>3475</td>
<td></td>
</tr>
<tr>
<td>Price of outdoor work in the cold season*, €M</td>
<td>44</td>
<td>62</td>
<td>140</td>
<td>124</td>
</tr>
<tr>
<td>Cold-related additional personnel costs (% of all personnel costs, estimate)</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Total cold-related additional personnel costs, €M</td>
<td>9</td>
<td>12</td>
<td>28</td>
<td>49</td>
</tr>
</tbody>
</table>

* the price of a work year = €40,000 = the average yearly salary of a construction worker, including side costs, at the time of the study.

6.3.2 Profitability of cold risk management

A cold risk management plan was compiled for a construction site where the foundation and frame of the building were built in the winter. The construction site was identical to pilot sites I, II and III, with 20 workers. The prices that were used in the calculations were real prices from construction site I. The average salary of a construction worker was €12.50/hr, plus 68% in side costs. The calculations included specific activities undertaken to manage cold-related health and safety risks. Routine OS measures, which are based on the general OSH laws or trade agreements, were not included in the calculations. The achieved savings were estimated by calculating the direct savings that could be identified and measured at the site, such as saved work hours or decreased material loss.

The calculations show that cold risk management activities brought about directly measurable savings that were nearly 2.5 times the cost of the activities (Table 6). The savings came from saved work hours, saved material and rental costs. On the other hand, costs and savings related to quality problems, occupational accidents or the health aspects of the workers could not be measured in this short-term evaluation study.
Table 6. Cost and savings of cold risk management at a construction site. Summary of table 2 in Article III.

<table>
<thead>
<tr>
<th>Cold risk management activities and their costs (€)</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparing the cold work plan:</td>
<td></td>
</tr>
<tr>
<td>Cold work plan is compiled by the foreman. Salary costs €6.</td>
<td>Not measured.</td>
</tr>
<tr>
<td>Assessing cold-related risks:</td>
<td></td>
</tr>
<tr>
<td>Assessment of cold risks in conjunction with work safety inspections (2 times), corrective actions are planned. Salary costs €42.</td>
<td>Not measured.</td>
</tr>
<tr>
<td>Organizational cold risk prevention activities:</td>
<td></td>
</tr>
<tr>
<td>Locations are reserved for weather shelters and brick storage.</td>
<td>Not measured.</td>
</tr>
<tr>
<td>Alternative indoor work is planned for the coldest days, on average 1 day per winter. Salary and machinery costs €1,194.</td>
<td></td>
</tr>
<tr>
<td>Technical cold risk prevention:</td>
<td></td>
</tr>
<tr>
<td>Isolating the metal handles of hand tools. Costs €252.</td>
<td>Not measured</td>
</tr>
<tr>
<td>Building a weather shelter for the bar-bending table. Salary and material costs €270.</td>
<td>No need for snow removal. Savings in salaries €1,694.</td>
</tr>
<tr>
<td>Building weather shelters and renting sport heaters for bricklaying work. Salary, material and rental costs €910.</td>
<td>Savings in salaries, materials and rental costs €8,622.</td>
</tr>
<tr>
<td>Cold protective clothing and personal protective equipment:</td>
<td></td>
</tr>
<tr>
<td>Cold protective outer clothing, protective gloves, polypropylene inner gloves and thermal caps are bought for the workers. Additional costs €1,429.</td>
<td>Not measured</td>
</tr>
<tr>
<td>Information campaign:</td>
<td></td>
</tr>
<tr>
<td>Cold work guides and information posters. Material costs €22.</td>
<td>Not measured</td>
</tr>
<tr>
<td>Total costs €4,183.</td>
<td>Total savings €10,316.</td>
</tr>
</tbody>
</table>

6.4 Implementation and sustainability of the development results in case organization FMA (IV)

6.4.1 Outcomes, implementation and influential factors

In the questionnaire, the respondents reported improved cold risk management activities. The activities had been initiated by the FMA’s OSH organization, by OHC units and by the cold work development project. The GBD’s respondents reported significantly more activities started by the development project than did the respondents from other divisions (Table 7). The most concrete improvements had occurred in the availability and quality of protective clothing (46% of the respondents). Improved technical cold protection measures, such as availability of
spot heaters and improved machinery, were reported. Awareness and occupational safety in general had also improved.

Table 7. Cold work questionnaire at the Finnish Maritime Administration in 2003. Reported improvements in cold risk prevention and cold protection activities during the past four years. The responses from the Gulf of Bothnia Division (GBD) are compared with the responses from other divisions.

<table>
<thead>
<tr>
<th>Improvements</th>
<th>GBD</th>
<th>other divisions</th>
<th>total</th>
<th>Fisher's exact test (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activities initiated by the cold work project</td>
<td>51</td>
<td>21</td>
<td>26</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>New cold protection clothing</td>
<td>40</td>
<td>45</td>
<td>44</td>
<td>p = 0.617</td>
</tr>
<tr>
<td>Activities initiated by the OS personnel*</td>
<td>35</td>
<td>31</td>
<td>32</td>
<td>p = 0.704</td>
</tr>
<tr>
<td>Activities initiated by the OHC personnel**</td>
<td>30</td>
<td>21</td>
<td>22</td>
<td>p = 0.285</td>
</tr>
<tr>
<td>Technical improvements</td>
<td>26</td>
<td>29</td>
<td>28</td>
<td>p = 0.847</td>
</tr>
</tbody>
</table>

Notes: * occupational safety, ** occupational health care, Bold signifies statistical significance.

In the interview, 19 persons out of 20 considered the cold work development project, carried out together with an external expert organization, important. The interviewees recognized many successful outcomes of the development phase, such as the guide for cold work (19 comments), the questionnaire survey (11) and the training sessions (7). The Finnish Maritime Administration’s Guide to Cold Work (Risikko et al. 2001) was considered a versatile and clear information package, and everybody received it. The training was considered to be in-depth and based on the newest knowledge. On the other hand, the respondents felt that standardized instructions were not established completely (10). Longer training periods and more advanced information was also needed (7).

According to the interviews, the most notable concrete improvements in the implementation phase were better availability and quality of protective clothing (7 comments), improved awareness and motivation (2), better planning of work and improved overall work safety (3). According to three interviewees, the effects of cold work had been taken into consideration in OHC activities. However, further training and implementation of the recommendations and results were carried out insufficiently by the FMA. According to one respondent, just a small part of the project results had been utilized. More information was needed.

According to the interviews, there were several influential factors that had either helped or hindered implementation of the development results. After the development phase, there were positive expectations regarding implementation
and continuous development. Good practices had been disseminated and further implementation of the results was suggested (2). Further training and information were needed (10). The OS personnel were suggested to be the coordinators in the continuous development process (4). The hindering factors were mostly related to lacking or unclear common rules, practices and knowledge at various levels of the organization (1). Procurement of protective clothing and PPE was considered problematic due to a lack of common practices and knowledge (10). More information about the properties of protective clothing was needed to support their purchase (4). The management’s attitudes towards further implementation of the results were considered positive in theory, but they did not lead to concrete actions (4). Moreover, during the follow-up survey, the FMA was also undergoing a major reorganization, which may have taken most of the attention (2). Other hindering factors were the lack of resources (4) and no coordinated training. The number of full-time OS staff was also considered to be too low (2).

6.4.2 Changes in perceived cold-related risk factors and effects

In the questionnaire survey, no significant changes were found in perceived cold-related environmental risk factors among all FMA respondents (N = 314), the respondents from the GBD or the respondents from other divisions, when compared with the earlier questionnaire study. The only significant change was in the sensation of wet hands, which had increased from 67% to 74% (p = 0.047) among all FMA respondents. In a comparison between the responses from the northernmost GBD and those from other divisions, the respondents from the GBD reported significantly higher ratings in wetness (98% versus 81%, p = 0.001), cold environment (96% versus 80%, p = 0.007) and cold materials (88% versus 71%, p = 0.020) than did the respondents from other divisions. The same phenomenon was seen in the earlier questionnaire survey.

When compared with the earlier questionnaire, there was a significant change in the perceived adverse effect of cold on work performance among all FMA respondents (Table 8). However, this change was not seen in the subgroup of the GBD. On the other hand, no significant differences in perceived cold-related detrimental effects were seen between the responses from the GBD and other divisions, despite the fact that the GBD respondents reported more cold-related risk factors. A summary of the development and implementation activities, outputs and perceived effects is presented in Table 9.
Table 8. Cold work questionnaires at the Finnish Maritime Administration. The detrimental effects caused by cold as reported in the questionnaire conducted in 2003 versus the earlier questionnaire, conducted in 2000 by Juopperi et al. (2000).

<table>
<thead>
<tr>
<th>All respondents</th>
<th>Questionnaire 2003 (N = 314)</th>
<th>Questionnaire 2000 (N = 631)</th>
<th>Fisher's exact test (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Adverse effects caused by cold</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold increases occupational accident risks</td>
<td>66</td>
<td>64</td>
<td>p = 0.820 *</td>
</tr>
<tr>
<td>Work is disturbed by cold-related discomfort</td>
<td>65</td>
<td>59</td>
<td>p = 0.055</td>
</tr>
<tr>
<td>Cold decreases work motivation</td>
<td>58</td>
<td>56</td>
<td>p = 0.727</td>
</tr>
<tr>
<td>Cold decreases work performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All respondents</td>
<td>52</td>
<td>44</td>
<td>p = 0.031</td>
</tr>
<tr>
<td>Respondents from the GBD**</td>
<td>56</td>
<td>57</td>
<td>p = 1.000</td>
</tr>
</tbody>
</table>

Notes: * Pearson Chi-Square test, ** Gulf of Bothnia Division, Bold signifies statistical significance
Table 9. Evaluation of the outputs, implementation and effects of the development process at the Finnish Maritime Administration (FMA). The rows PLAN, DO and CHECK describe the development phase, the row ACT describes the implementation phase.

<table>
<thead>
<tr>
<th>Interest level</th>
<th>Organization level</th>
<th>Action level</th>
<th>Awareness level</th>
<th>Support level</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLAN</td>
<td>Present state analysis: Several different quality and occupational safety (OS) management practices at the FMA. Need for common cold risk management practices</td>
<td>Cold questionnaire, Workplace assessments in the pilot division. Plan for immediate cold risk management activities</td>
<td>Need for information recognized throughout the FMA</td>
<td>OS and occupational health care (OHC) personnel participated as key actors in the project</td>
</tr>
<tr>
<td></td>
<td>DO</td>
<td>Workshops for a Cold Risk Management Model for the FMA</td>
<td>Training &amp; cold risk management trials done in the pilot division and its workstations</td>
<td>The FMS’s Cold Work Guide was produced and delivered to everyone</td>
</tr>
<tr>
<td></td>
<td>CHECK</td>
<td>Recommendations given for establishing standardized instructions and common practices for cold work</td>
<td>Immediate positive feedback about the activities. Recommendations given for further development and training</td>
<td>Immediate positive feedback. Information exchange between divisions and workplaces</td>
</tr>
<tr>
<td></td>
<td>ACT</td>
<td>OS organization noted as one of the initiators of the development. However, OS rules and practices for the whole organization are not clear. Further implementation of the results done only partially. Reasons: limited funding and time resources, large organizational changes, shortage of full-time OS personnel</td>
<td>Improvements noted: planning of the work, technical cold risk preventive measures, cold protection clothing, overall OS and comfort in cold work. However, further implementation of the results is done only partially. Reasons: poor clothing procurement system, no coordinated training, insufficient instructions for workplaces. No measurable improvements in perceived cold-related problems</td>
<td>Improved general knowledge, awareness and attitudes towards development. More beneficial activities reported in the pilot division than in other divisions. The management’s positive attitudes did not lead to concrete actions at the organization level. Need for more information</td>
</tr>
</tbody>
</table>
6.4.3 Safety Management Matrix

During the evaluation study in Article IV, a matrix model was developed for analyzing activities during the planning and implementation process. The matrix model was used in Article IV (Table 9) to summarize the outputs, implementation and effects of the development process at the FMA. At the same time, an idea was born for potential use of the matrix model in different types of OS and ergonomics development processes. The matrix model was named the Safety Management Matrix. The Safety Management Matrix combines the PDCA model as a theoretical and also chronological framework for the development and implementation process together with four different interest levels at which the activities take place. The interest levels are: the organization level, the action level, the awareness level and the support level (Table 10). The Safety Management Matrix was further developed in this study, and it is not presented in Article IV in the form it appears in Table 10.
Table 10. General Safety Management Matrix.

<table>
<thead>
<tr>
<th>Interest level</th>
<th>Organization level</th>
<th>Action level</th>
<th>Awareness level</th>
<th>Support level</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLAN</td>
<td>Analysis of the present state: OSH* and SHEQ** management systems and practices.</td>
<td>Plan for immediate concrete improvements</td>
<td>Need for information is surveyed, training sessions are planned</td>
<td>Internal and external OSH experts participate in the planning phase of the process</td>
</tr>
<tr>
<td></td>
<td>Goals set for common OSH practices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>Development of common rules and practices</td>
<td>Initial concrete improvements are made at the pilot workstations</td>
<td>Training and information.</td>
<td>Active support in the development process</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Production and delivery of guidance material</td>
<td></td>
</tr>
<tr>
<td>CHECK</td>
<td>Checking the usability of the developed rules and practices. Establishing standardized organization-wide practices, allocation of resources, naming the key persons</td>
<td>Feedback from the activities.</td>
<td>Feedback, further training needs and ideas</td>
<td>Evaluation of the tested internal and external support practices. Establishment of cooperation practices and agreements</td>
</tr>
<tr>
<td>ACT</td>
<td>Implementation of the developed rules and practices in the whole organization.</td>
<td>Dissemination of good practices</td>
<td>Continuous comprehensive information and training system</td>
<td>Internal and external expertise used on a continuous basis</td>
</tr>
</tbody>
</table>

Notes: * Occupational safety and health, ** Safety, health, environment and quality
7 Discussion

7.1 Results and their implications and limitations

7.1.1 Managing OSH risks in cold work— a systematic approach

The Cold Risk Management Model was developed by following a generally accepted principle of continuous improvement (Deming 1986, ISO 9001), which is present in TQM approaches. The approach of the Cold Risk Management Model is in accordance with the principle of continuous development. It is thus compatible with the OHSAS 18001 specification and the ISO 9001 and ISO 14001 standards (OHSAS 18001, ISO 9001, ISO 14001). The methods were based on validated risk assessment and management methods and standards (Malchaire et al. 1999). They can be integrated in occupational health and safety practices in various industries involving cold work. However, the model may need some simplifications for industries that conduct process-type cold work in which work conditions are stable. The applicability of the Cold Risk Management Model and its methods in novel, customer-oriented quality management systems and trends could also be studied further.

According to the feedback from the field tests and expert evaluation, the methods were usable after a short introduction period. The continuum between the cold risk assessment checklist (Mäkinen et al. 2002b) and the cold work plan worked well, although there was some overlap in the documentation. The overlap is partly due to different functions and documentation purposes. The cold work plan functions as a tool in the planning stage (P) of the PDCA cycle. It helps the company attack and solve cold-related problems as early in the process as possible. This approach has proved to improve the safety, quality and productivity of work and to lower costs caused by faults in the process (Deming 1986, Hutchison 1997, Niskanen 1993). The cold risk assessment checklist (Mäkinen et al. 2002b), on the other hand, is meant to be used as a regular OS monitoring tool, as an initial assessment tool in a totally new workstation or as an ad hoc tool in the middle of the PDCA process if work conditions or the contents of the work change drastically. In an ideal situation, cold risk management practices are well planned in advance, carried out systematically and checked regularly. The primary user groups for the methods are the foremen, workers’ occupational safety delegates, OS personnel and OHC personnel of a company.
The development and evaluation of the Cold Risk Management Model was carried out in a limited number of industries and workplaces. This, of course, causes limitations to its applicability. However, the various workplaces in Articles I, II, III and IV had very challenging work conditions, such as changing weather conditions, variable work tasks, repetitive work, high risk of occupational accidents, a large amount of manual work and the presence of wind and moisture. To complement the data, feedback on the applicability of the model was gathered from an OSH expert group representing a wide variety of industries. It is thus suggested that the Cold Risk Management Model and related methods may be used in a large variety of cold workplaces.

7.1.2 Contribution to ISO 15743

The results of this study have already been utilized in the preparation of ISO 15743 Ergonomics of the thermal environment – Cold workplaces – Risk assessment and management (ISO 15743). The prepared standard, ISO WD 15743, was confirmed as ISO 15743 in 2008 and ratified also in Finland as SFS EN ISO 15743. The Cold Risk Management Model forms an essential part of the standard. The standard is applicable to both indoor and outdoor work situations, on shore and offshore, but not for work conducted under water. (ISO 15743)

The cold risk management plan and guidelines were included in ISO 15743 in Annex C: “Guidelines for planning and managing cold work”. The standard also includes the cold risk assessment procedure checklist (Mäkinen et al. 2002b). The standard also includes a questionnaire intended for use by OHC professionals to identify individuals with symptoms that increase their cold sensitivity, guidance material for OS and OHC professionals, guidelines on how to apply thermal standards and other validated scientific methods when assessing cold-related risks (Hassi et al. 2003).

7.1.3 Applying the Cold Risk Management Model and related methods in the case companies’ SHEQ systems and practices

The research-assisted development work was carried out in two case companies (Articles II and IV). Various employee groups and a wide variety of tasks in the construction industry and in maritime services were represented in the cases. The feedback from the development work was used to further refine the Cold Risk Management Model and related methods.
The development activities had immediate positive effects in both case organizations. The training associated with clothing trials had an effect on the awareness and attitudes of the workers. The workers felt they had received new information, and the training encouraged the workers to take responsibility for their own comfort, health and work performance in cold work. The employees also showed willingness to contribute in procurement of additional clothing and equipment for cold work together with the employee. The motivation for further development was high. Although without sufficient statistical data, it seems that visible concrete activities in the early stage of the development process increase the personnel’s motivation towards further development.

The development projects in the case companies were carried out in different workstations. The development process followed the principle of continuous improvement, instead of a focused intervention study. For this reason the cold risk prevention activities were further developed at later pilot sites, instead of copying them as is from the first site. For the same reason, there were no control groups. In this study, good cold risk management methods were found, and they are applicable in various workplaces. However, it is extremely important to plan (to tailor) concrete cold risk management activities in and for each individual unit or workplace. For this reason it is also more time-consuming and challenging to utilize, transfer and further develop these good practices, products and processes (Mäntyneva et al. 2005).

In this study, the effects of the Cold Risk Management Model could not be tested in a large number of workplaces. The affecting factors, which should be taken into consideration in a large-scale effectiveness study, are variations in weather conditions between the different years, the features of the workplace, changes in the personnel and the subcontractors and other ergonomic development activities conducted at the same time.

However, some follow-up data are available from analogous systematic OS models and methods. In Finland, the TR safety observation method has led to positive improvement in the safety index and to more profitable operation in a large number of construction sites (Kemppilä et al. 2002). A safety leadership model developed by Simola (2005) was connected to a clear decrease in lost-time injury-frequency rates (LTI) and positive trends in other safety performance indicators. (Simola 2005.)

The subcontractors’ role was not studied separately. In the case study in Article II, the subcontractors’ workers participated in the development activities and feedback discussions at the construction sites. The requirements for
subcontractors in the Cold Risk Management Model were discussed, but no thorough evaluation of the procedure was done. It is suggested on the basis of this study that the Cold Risk Management Model may be utilized as a common tool in shared workplaces, where several suppliers or subcontractors operate together in the same work environment. This approach is supported by previous studies. For example, positive preliminary results were achieved in a follow-up study on the Finnish Occupational Safety Card (OSC) system (Väyrynen et al. 2008).

7.1.4 Costs of cold work - profitability of managing cold risks

Working in the cold increase the personnel costs of a company. According to the case study in a construction company, the main additional costs were attributable to a decrease in productivity. When the foundation of a building was laid and the framework was erected in winter, this entailed up to a 30% increase in work hours per built cubic meter compared with the identical construction sites that were started during the warm season. While the different competences of the various construction teams may explain a maximum of 10% of this difference, 20% more work hours were needed in the wintertime.

The costs were further assessed specifically in bricklaying work, including assisting work. The price of bricklaying work per square meter was up to 27% higher for the company in the cold season compared with the warm season. Likewise, the bricklayer’s wages were up to 16% lower during the cold season than in the summer. The case study showed that in construction work, economic losses are accrued by both the company and the workers. The economic losses in the whole construction industry are large. According to the assessments in the case company and the statistics, working in the cold was estimated to increase personnel costs in the construction industry in Finland annually by €50M. This represented 3% of the industry’s annual personnel costs at the time of the study. While decreased productivity was the major additional cost factor in the calculation, there are other cost types whose effects may become visible in the long term and in larger populations.

The study showed that it is possible, and economically profitable, to reduce cold-related adverse effects through systematic planning and actions at companies and workplaces. The Cold Risk Management Model provided an effective tool for controlling additional personnel costs caused by cold at the construction site. In the case construction site of 20 workers, the savings achieved by cold risk management activities were more than twice the costs of those activities. The
achieved savings (roughly €10,000) exceeded the costs (roughly €4,000) already
during the time when the foundation and framework of the building were built. In
the case construction company, the most suitable practice was to include the cold
work plan as a part of the general work safety plan of the site. All measures,
responsibilities and timetables required for cold risk management were recorded
in the cold work plan well in advance. The measures to reduce costs are
applicable to the whole construction industry.

The possible long-term effects of cold risk management activities on quality,
occupational accident rates and the health of the workers would only show over a
longer term, and could not be included in the calculations of this case study.
While there is evidence that there is a relationship between ergonomic
improvement and improved productivity (Ichinovski et al. 1995) or other
favorable economic benefits (Anderzen & Arnetz 2005, Hendrick 2003, Johanson
1997), it is anticipated that the economic benefits would be even higher if these
effects could be measured reliably. The outcomes of this study may also be used
as one example for evaluating the costs and profitability of ergonomics
development and OS activities at workplaces.

At the national level, the largest sickness costs in Finland in general result
from early retirement. The biggest proportion of retirement costs come from lost
labor input. (Ahonen 1996). While cold conditions are connected to the
occurrence of common colds (Mäkinen et al. 2008), cardiovascular and
musculoskeletal diseases (Hassi et al. 2000, Oksa et al. 2006, Pienimäki 2000)
and the risk of occupational accidents (Pekkarinen 1994, Hassi et al. 2000), it is
reasonable to claim that increased cold risk prevention and cold protection actions
at workplaces will result in significant economic savings at the national level, too.

The size of the sample and especially the duration of the follow-up period in
original study (Article III) cause limitations to the results. However, the
construction site was optimal for the cost analysis in this study, because three
similar apartment buildings were built at the site at different times of the year. The
buildings were identical in terms of their construction and required work phases.
The data were analyzed so that a clear picture was formed about the quality of the
additional personnel costs related to cold conditions. The share of the different
personnel cost types was difficult to measure, as not all the necessary information
was available. The measures to reduce costs are, however, applicable to the whole
construction industry.
7.1.5 Improving implementation and effectiveness

The study provides long-term evaluation information from a multi-component ergonomic development and implementation process and its perceived effects in one case organization. As mentioned before, evaluation of the effectiveness of an individual intervention program is a challenging task, as there are always several other affecting factors (Kantanen 1997, Rissanen et al. 2003, Kristensen 2005, Nielsen et al. 2006). The long-term effects of cold risk management on the OSH in terms of lost-time injury-frequency rates (LTI), occurrence of the cold-related illnesses at work or other health or safety performance indicators could not be evaluated.

The size of the sample and the duration of the follow-up period in the evaluation study (Article IV) cause limitations to the generalization of the results. The number of questionnaire respondents was lower than in the previous questionnaire three years earlier. There are several reasons for this. The evaluation questionnaire was not re-sent to the study group, unlike the first questionnaire. Some of the OSH key persons who carried out the follow-up study were not involved in the initial development process, which may have lowered their motivation towards the study. The lower response rate may also be a sign of selecting too broad a study group from the beginning. Most probably there would have been a higher response rate and more positive changes in the end if the evaluation survey had been focused on the pilot group only, as also noted by Semmer (2006). However, the characteristics of the respondents were similar to those in the earlier questionnaire, and the survey thus well reflected the whole FMA personnel.

According to the evaluation, the outcomes from the initial development phase were useful and usable. Implementation of the good practices succeeded well in the pilot group, and positive changes in concrete cold risk prevention activities were found. The personnel’s expectations towards further implementation were high. This is most probably due to the successful development and information activities during the development phase. At the organization level, no improvements in the organization-wide rules and practices were found. Ownership of the implementation was not clear and managerial commitment and allocation of resources were vague. One of the biggest reasons for this was most likely the company’s major reorganization process, which started a year after the initial development phase at the case organization. At the support level, the OS and OHC personnel of the case company were recognized as key actors in the
implementation process, but their role did not become clear and visible. External expertise was needed also for the implementation process.

This study points out the importance of visibility and concrete development activities, organization-wide instructions and management practices, commitment and ownership of the process, as well as information and awareness as the most important factors of facilitating an implementation process in a large, hierarchically multilevel and geographically widely spread organization. The implementation process, with allocated resources and clear ownership of the process, should be planned at an early stage, and it should be updated when needed. To ensure the sustainability of the results, internal and external expertise should be used also after the initiation phase (Gyekye et al. 2007, Ljungström 2005). It is assumed that the most important helping and hindering factors of the implementation process were found. The helping and hindering factors are suggested to be applicable in various types of ergonomics development and implementation processes. These factors are also found in previous studies (Eason 1990, Fullan 1991, Podgórski 2005, Väyrynen et al. 2004, Whysall et al. 2006). Only a few studies emphasize especially visibility and concrete activities, which were found very important in this study (Rissanen et al. 2003). This study supports the previous idea that multi-component development processes that are intended to bring about changes in more than one element in the organization or work system are the most effective (Lehtola et al. 2008, Lindbäck et al. 2006, Saarela 1991, Silverstein & Clark 2004). A participatory approach in the intervention or development programs has proven to be successful (Saarela 1991, Saarela 2000). Rissanen et al. (2003) also pointed out the importance of correct timing.

In a large and hierarchically multilevel organization, such as the case organizations of this study, the time span for implementation and diffusion of new practices is long, up to 3–10 years (Fullan 1991). The case organization FMA received a national OS award “Kaiku” in 2007, based on committed and long-span work towards safer work and work conditions. During the years the work methods, equipment and PPDs have improved. This had decreased the occupational accident rate and improved the productivity of the work. The personnel had become more active in improving their own work and work environment. The OS issues had been integrated into the organization’s management system. (Rissa 2007). According to the OS and OHC key persons of the FMA, OS in cold conditions was one of the central themes in this long improvement process, and the cold work project (1999–2001) was one of the
most important initiators in improving the general OS issues at the FMA. Even though the OS award is not based on any scientific evaluation, it still suggest that the results of the cold work development project were implemented and diffused through the whole organization six years after the initial development phase. This is an interesting point, as organization-wide implementation appeared to be poor in a follow-up study conducted three years after the initial development phase. Was implementation still ongoing?

7.1.6 Matrix model for development, implementation and evaluation

As a new method and a new result as such, a Safety Management Matrix was developed for analyzing and evaluating activities in the different phases of a development process. The Safety Management Matrix is formed from the development framework of PDCA and the four interest levels at which the activities or changes take place: the organization level, the concrete action level, the awareness level and the supporting expertise level. It is suggested that the matrix can also be used as a proactive tool in various development processes in the field of safety management or ergonomics. The primary use of the Safety Management Matrix hints that the matrix could provide a useful tool for tracing and evaluating reasons and consequences between various activities throughout the development process. Further, it might be usable in other types of development processes, where there is a company and external expert organizations working together. These could be, for example, cooperation activities targeted towards generating new innovations (Ramstad 2008).

7.2 Utilization and dissemination of the results

After the original studies, the results have been exploited at the national and international levels in producing instructions, guidelines and learning material for OSH practices in cold work.

The Cold Risk Management Model, the cold work plan and concrete examples for cold risk management activities were included in the Guide for Cold Work, which was published in Finnish (Opas Kylmätyöhön), Swedish and Norwegian (Hassi et al. 2002, Risikko et al. 2002). The guide was targeted at occupational health and safety personnel, foremen, occupational safety delegates and experts. In order to complement the guide, a method handbook for cold work, accompanied by a user training package, has been prepared and published in
Finnish (Menetelmäkäsikirja kylmätööhön) as a practical planning tool for foremen and OSH personnel (Risikko et al. 2004). The method handbook contains the cold risk assessment and management methods on a CD. The method handbook had an interactive user interface, and the methods can be used with a web browser or printed (Figure 11).

Fig. 11. The principle of the user interface in the method handbook for cold work (translated from Risikko et al. 2004, with permission of all authors and publishers).

The results have also been utilized in cold work guides for various other employee groups and industries. Guides were written also for the transportation industry and stevedoring work in cooperation with the Centre for Occupational Safety (Hassi et al. 2001a, 2001b, Risikko et al. 2000b, 2001). The information has also been utilized in an Occupational Safety Information Card, “Working in the Cold”, by Rintamäki (http://www.ttl.fi/NR/rdonlyres/5F9295A1-7FB7-49CF-BDAD-BA355C0EB281/0/Tietokortti2.pdf).

The results of the original studies (in Articles I and II) have also been utilized in vocational training (Toivonen & Risikko 2001). The produced guidelines for OHC regarding cold work (Hassi et al. 2003) were included in a comprehensive
7.3 Suggestions for further studies

The results of this study have been exploited in practice already. However, there are still not enough follow-up data about implementation and long-term effects of the Cold Risk Management Model in different types of workplaces. Systematic intervention studies are suggested to enhance the good practices for implementation of the cold risk management activities. The applicability of the Cold Risk Management Model and its methods in novel, customer-oriented quality management systems and trends could also be studied further. Long-term follow-up studies are suggested for studying the effects of systematic cold risk management activities on occupational accident rates, cold-related sicknesses, productivity and the quality of production.

The experiences gained from this study may also be applicable in other types of development and implementation processes and intervention studies in the field of ergonomics and safety management. In order to enhance the implementation of multi-component development processes, the interaction between the development elements, activities, and the actors of the process needs to be studied further, as suggested before by Anderson et al. (2005). A specific question for further study is the cooperation and optimal roles of internal and external experts in different phases of development and implementation processes. It is suggested that the Safety Management Matrix presented in this study could be utilized to analyze development and implementation activities, actors and outputs during the planning, development and implementation stages in various kinds of ergonomics and work environment development processes.

It is also suggested that the presented matrix model could be tested and eventually utilized in studying the interaction between activities and actors in other types of development processes, too. For example, the interaction between enterprises, research and education organizations and business development organizations in promoting new business innovations and social innovations is a current topic and should be studied further.
8 Conclusions

1. A systematic Cold Risk Management Model was created in this study. The Cold Risk Management Model can be integrated systematically into a company’s SHEQ systems and activities. The Cold Risk Management Model is accompanied by methods: a cold risk management plan and guidelines for selecting the most appropriate concrete cold risk prevention in the workplace. The Cold Risk Management Model forms an essential part of ISO 15743 Ergonomics of the thermal environment – Cold workplaces – Risk assessment and management. The cold risk management plan and the guidelines were included in ISO 15743 in Annex C: “Guidelines for planning and managing cold work”. According to the feedback from the workplaces and OSH professionals, the Cold Risk Management Model and related methods can be used in different types of cold indoor and outdoor work. The developed methods are easy to use after a short introduction. Some simplification may be needed in process-type work, where the tasks and ambient conditions are rather constant. It is also suggested on the basis of this study that the Cold Risk Management Model and related methods may be utilized as common tools in shared workplaces where several suppliers or subcontractors operate together in the same work environment.

2. The Cold Risk Management Model and related methods were applicable, and the concrete cold risk management actions resulted in immediate positive feedback in case studies in two companies in the fields of construction and maritime administration and services. Training associated with clothing trials and practical learning material had an effect on the workers’ awareness and attitudes. Although without sufficient statistical data, it seems that visible concrete activities in the early stage of the development process increase the personnel’s motivation towards further development.

3. Based on the study in a construction company, cold work causes additional personnel costs to the company. The largest costs were caused by the lower productivity of outdoor work in the winter time. At a national level, working in the cold was estimated to increase the personnel costs in the construction industry annually by €50M, which was 3% of the industry’s annual personnel costs. Based on the case study in a construction company, cold risk management activities are economically profitable. For a construction site of 20 employees, the savings achieved from cold risk management activities were roughly 2.5 times the costs of those activities.
4. In a follow-up study, the initial development project for cold risk management was considered successful in the case organization in the field of maritime administration and services. Concrete improvements and increased awareness towards cold work and further development were shown. Organization-wide implementation of cold risks management practices, on the other hand, was done only partially by the case organization, the main hindering factors being a lack of company-wide rules, a lack of expertise and resources, poor managerial commitment and a large re-organization process occurring at the same time. According to this study, the following factors should be emphasized to enhance the implementation process: clear focusing of the target groups, early establishment of organization-wide rules and practices, visibility, concrete activities and extensive training campaign, clear responsibilities and sufficient resources for implementation, and availability of internal and external expertise in all phases of the process.

5. As an additional result, a Safety Management Matrix was developed for analyzing development and implementation activities during the process time span. The matrix is formed from the process phases plan (P), do (D), check (C) and act (A) and four interest levels: organization level, concrete action level, awareness level and support level. The matrix is suggested to be used as a proactive planning and evaluation tool for various types of development processes.
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107


110


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Vernon HM (1919) An investigation of the factors concerned in the causation of the industrial accidents. Health of Munitions Workers Committee Memo No 21, CD 9046.


Appendix 1 A Checklist for assessment of the cold risks at workplaces


A CHECKLIST FOR IDENTIFYING COLD-RELATED PROBLEMS AT WORK

HOW TO USE THE CHECKLIST

1. Consider the working environment as a whole. Before using the checklist, go through the different activities to be observed and categorize the prevailing working situation to include all the circumstances that are likely to arise during a day and for a foreseeable period of time. Then apply the checklist separately to each activity. If it is not possible to consider all the separate tasks involved in the work, apply the checklist later. If several employees are engaged in the same work, apply the checklist to the individual who in your opinion has the most problems in the cold.

6. Check through each condition/category separately and indicate the score that corresponds best to the situation. The score 0 implies that no preventive actions are needed, 1 that certain cold-related problems exist and should be dealt with in the long term, and 2 that there are cold-related problems which may involve a risk of impaired health and performance and that corrective action should be taken immediately to reduce or eliminate the problem.

7. Add remarks or more precise observations on each condition, e.g. that the worker is poorly protected against the wind, that gloves are not used at all etc. These remarks will be of help when the results are interpreted.

8. When should the checklist be applied?
   a) a few times during the winter (once a month and/or if environmental conditions change)
   b) b) when the nature of the work alters substantially
   c) c) when the working environment alters substantially
   d) d) after new preventive measures have been introduced
CHECKLIST FOR THE IDENTIFICATION OF COLD-RELATED PROBLEMS

Date:  
Name of company:  Temperature…..°C  
Working activity observed:  Wind m/s

Scoring:

0 No need for preventive actions  1 Corrective actions are recommended in the long term  2 Immediate need for corrective action

1. Cold air
0 Air temperature does not cause any problem
1 Air temperature causes certain problems
2 Air temperature causes obvious problems
Remarks:________________________________________________

2. Wind/air movements
0 No air movement
1 Light air movement (e.g. sensation of draught, light wind)
2 Pronounced air movement (e.g. strong wind blowing occasionally or repeatedly)
Remarks:________________________________________________

3. Contact with cold surfaces while handling tools/materials, or sitting, kneeling or lying on cold surfaces
0 Not at all
1 Working for short periods with thin gloves, sitting, kneeling or lying on cold surfaces
2 Working with bare hands or for longer periods sitting, kneeling, standing or lying on cold surfaces
Remarks:________________________________________________

4. Exposure to water/liquids/damp
0 No exposure
1 Short periods of exposure (e.g. when handling cold materials, working in rain or snow etc.)
2 Long periods of exposure (e.g. continuously handling cold fluids or wet materials etc.)
Remarks:_________________________________________________
5. Protective clothing against the cold (excluding the hands, feet and head)

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Sufficient</td>
</tr>
<tr>
<td>1</td>
<td>Partly insufficient (e.g. only some winter clothing in use)</td>
</tr>
<tr>
<td>2</td>
<td>Insufficient (e.g. no protective clothing used although needed)</td>
</tr>
</tbody>
</table>

Remarks: __________________________________________

6. Protection against the cold: hands, feet, head (estimated in relation to the prevailing conditions). The examples in parenthesis represent mainly protection against very cold weather.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Sufficient (e.g. inner gloves and mittens, winter boots with thick soles and loose insoles, windproof winter hat covering the ears)</td>
</tr>
<tr>
<td>1</td>
<td>Fairly good (e.g. gloves with a lining, winter shoes with thick soles, a safety helmet with inner cap or a non-windproof hat)</td>
</tr>
<tr>
<td>2</td>
<td>Insufficient (e.g. gloves without a lining, no gloves, shoes with thin soles, a safety helmet without an inner cap, or no hat)</td>
</tr>
</tbody>
</table>

Remarks: __________________________________________

7. Use of personal protective equipment (helmet, hearing protection, etc.)

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No interference with work</td>
</tr>
<tr>
<td>1</td>
<td>Interferes with work to some extent (e.g. clumsiness, restricted movements, impaired protection against the cold)</td>
</tr>
<tr>
<td>2</td>
<td>Considerable interference (e.g. considerable difficulties in combining cold protective clothing and use of PPE, or cold protective clothing/PPE not used at all)</td>
</tr>
</tbody>
</table>

Remarks: __________________________________________

8. Other cold-related problems

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Long-term cold exposure/working in the cold (e.g. continuously &gt;2 hrs)</td>
</tr>
<tr>
<td>1</td>
<td>Light work (e.g. measuring, monitoring etc.)</td>
</tr>
<tr>
<td>2</td>
<td>Highly varying workload (light/heavy)</td>
</tr>
<tr>
<td></td>
<td>Varying thermal environments (e.g. frequent moving between indoor and outdoor conditions)</td>
</tr>
<tr>
<td></td>
<td>Slipperiness</td>
</tr>
<tr>
<td></td>
<td>Insufficient lighting</td>
</tr>
<tr>
<td></td>
<td>Other factors, what?</td>
</tr>
</tbody>
</table>

 Remarks: __________________________________________
Evaluation of the results of the checklist and selection of corrective actions:

- Transfer the scores for the separate items (0, 1, 2) to the column scoring in Table 1.
- For the item Other problems, fill in the highest score observed. If several of the activities checked have gained the highest score, only one score is filled in. Each of these activities can be considered separately when evaluating the results and selecting preventive measures.
- A score of 1 indicates that no preventive measures are needed just now, but that improvements should be made in the company’s OHS system to improve the workers’ health and safety in the cold.
- A score of 2 indicates that preventive measures are needed immediately to reduce or eliminate adverse effects of cold conditions. Examples of management methods are given in Annex C.
- Propose a suitable preventive measure in Table 1. If the problem cannot be solved by simple management methods, place a cross in the column Need for further analysis.
- When evaluating the results and choosing the preventive measures one should be aware that there may be interaction between some of the factors. For example, cold air interacts with wind/air movements, similarly cold protective clothing with protection of the extremities, and water/liquids/damp with touching of cold materials and cold protective clothing etc. These interactions may aggravate the cold risk.
- Discuss the protective measures to be implemented with the management of the company.
- Set a date for re-check to assess the adequacy of the measures.
### Table 1: Summary of results and selected preventive measures

<table>
<thead>
<tr>
<th>No need for corrective action</th>
<th>Corrective action needed in the long term</th>
<th>Corrective action needed immediately</th>
<th>Scoring</th>
<th>Preventive measure Implementation</th>
<th>Need for Further Analysis</th>
<th>Date of Re-check</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cold air</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Wind/air movement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Touching cold surfaces</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Water/liquids/wetness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Protective clothing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Protection against cold: hands, head, feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Use of PPEs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Other problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 2 Cold questionnaire to the personnel of Joutsenkaari and Oravanpesä construction sites

The questions are translated from the original Finnish questionnaire. The cover letter and the respondent’s approval document are not included in this translated questionnaire.

Background Information

1. Name & address: ________________________________________________
2. Profession
3. Age: ______ years
4. Height: __________ cm
5. Weight: ________ kg

Work and Work Environment

6. Does your work contain the following factors, causing physical load?

<table>
<thead>
<tr>
<th>Factor</th>
<th>not at all</th>
<th>to some extent</th>
<th>a lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy physical work</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Monotonous work movements</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Standing still</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Work positions with bent, rotated or stretched back</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Continuous walking / moving</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Lifting or carrying objects</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Kneeling or crouching</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Work positions with arms lifted above shoulder line</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

7. The physical level of your work is mostly:

   Light work, sitting, manual work
   Mostly light work, sitting, handling heavier objects
   Light work, standing, moving, no heavy work phases, no handling or lifting heavy objects
   Intermediate work, moving, bending, carrying objects, walking, Walking on stairs
   Heavy work, standing, walking, lifting and carrying heavy objects
   Very heavy work, continuous heavy work movements
8. Do the following physical work environment factors cause harm to you?

<table>
<thead>
<tr>
<th>Factor</th>
<th>No harm</th>
<th>Some harm</th>
<th>A lot of harm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insufficient lighting, reflections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold work environment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold materials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind, draft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture, wetness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture to the feet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture to the hands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oils, acids, other chemicals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dust</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smells, gases</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. Have you had such aching, which has limited your daily activities during the last year, in the following body parts?

<table>
<thead>
<tr>
<th>Body Part</th>
<th>No</th>
<th>Very little</th>
<th>Some problems</th>
<th>A lot of problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head, neck and shoulders</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrists, hands, fingers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legs, calves</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hips, lower back</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knees, legs, calves</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankles, feet, toes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. If you feel cooling / cold-related problems at work, in which body parts?

<table>
<thead>
<tr>
<th>Body Part</th>
<th>No cooling / problems</th>
<th>Little cooling / problems</th>
<th>Some amount of cooling or problems</th>
<th>A lot of cooling and problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulders</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower back</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrists, hands, fingers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legs, calves, knees</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feet, toes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11. Do you sweat during the workday?
   - Yes
   - No

12. In your opinion, does cold increase risk for occupational accidents?
   - Yes
   - No
   - I do not know

13. Can you spend the breaks in a warm space?
   - Yes
   - No

14. How do you eat during the workday?
   - I do not eat during the workshift
   - I eat a warm meal at home, in a restaurant or in a lunch bar
   - I bring my own lunch and eat in the break room

15. Do you smoke?
   - No
   - Yes, approximately ________ cigarettes a day
16. Please mark the work tasks, in which you are involved, and the cold-related problems or harms in those work phases. You may add work tasks in the table, if needed.

<table>
<thead>
<tr>
<th>The construction phase or the work task</th>
<th>cold causes harms especially in the following body parts (you may choose several)</th>
<th>in which ambient temperature the cold-related problems start? (°C)</th>
<th>other adverse environmental factors?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preparing molds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete casting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Element installing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barbending and installing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wiring / heating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating tower crane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVAC – assisting tasks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVAC installing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heatpipe installing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage installing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrics installing</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Clothing and equipment**

17. Choose the outerwear set or sets, which you have used mostly at work in the last winter season in different ambient temperatures.

- [ ] One piece winter coverall with thick lining
- [ ] Winter jacket and trousers or salopettes with thick lining
- [ ] Winter overall with light lining
- [ ] Winter jacket and trousers or salopettes with light lining
- [ ] Coverall without lining
- [ ] Jacket and trousers or salopettes without lining
- [ ] Other set of clothing, which?
18. Choose the intermediate wear and underwear, which you have used mostly at work in the last winter season in different ambient temperatures (you may choose several).

<table>
<thead>
<tr>
<th>Choices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-sleeved cotton underwear</td>
</tr>
<tr>
<td>Long-sleeved mixed fiber underwear</td>
</tr>
<tr>
<td>Long-sleeved synthetic fiber underwear (so called thermal or sports underwear)</td>
</tr>
<tr>
<td>Intermediate clothing made of wool, fleece or pile</td>
</tr>
<tr>
<td>Intermediate wear made of cotton</td>
</tr>
<tr>
<td>Other set of clothing, which?</td>
</tr>
</tbody>
</table>

19. Do you need / use personal protective devices or other personal equipment?

<table>
<thead>
<tr>
<th>Device</th>
<th>No need to use</th>
<th>Use</th>
<th>Would need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hearing protective device</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory protective device</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protective gloves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye protection device, goggles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety shoes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety helmet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tool vest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toolbelt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee protectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platform for standing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spot heaters</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

20. Please evaluate, how well the protective clothing which you usually wear in cold season, protect you against various physical work environment risk factors.

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Well</th>
<th>Usually rather well</th>
<th>Poorly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Against cold air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Against wind</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Against wet snow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Against dirt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Against mechanical hazards</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

21. In which situations and work tasks the clothing does not provide enough protection? _____________________________________________

122
22. Is the water vapor permeability (breathability) of your protective clothing sufficient?

- No
- Most of the time
- Yes

23. Does the protective clothing hinder some of the work tasks?

<table>
<thead>
<tr>
<th>Task</th>
<th>No</th>
<th>Hinders sometimes</th>
<th>Hinders a lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stretching the arms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual tasks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotation of the torso</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bending</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating vehicles or machinery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climbing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeing, hearing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other tasks and movements, which?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

24. Describe the problems, which you named in the previous question. ______

25. ______

26. ______

27. Does the cold make the use of the personal protective devices more difficult? If yes, please specify how: _________________________________

28. Which of the following set of clothing options you would choose for outdoor work in cold season?

- 1. One-piece coverall
- 2. Separate trousers / salopettes and jacket
- 1. Clothing with thick lining
- 2. Clothing with thin lining plus an intermediate set of garments
- 1. Waterproof outer clothing
- 2. Separate rainwear

29. Your other comments and ideas: _________________________________
Appendix 3 Cold Questionnaire to the Finnish Maritime Administration’s Personnel, 2003

The questions are translated from the original Finnish questionnaire, which was conducted in 2003. The cover letter and the respondent’s approval document are not included in this translated questionnaire.

Background Information

1. Name & address: ________________________________
2. Gender:
   - [ ] Male
   - [ ] Female
3. Age: ___ years
4. Education: ________________________________
5. Profession, job in FMA: ________________________________
6. How many years you have worked in a work with cold exposure?
   - ___ years

7. Your maritime district
   - [ ] Gulf of Bothnia
   - [ ] Archipelago Sea
   - [ ] Gulf of Finland
   - [ ] Inland Waterways
   - [ ] Central Administration, on-shore
   - [ ] Central Administration, ice breakers
   - [ ] Central Administration, maritime safety measures

Work and Work Environment

8. Your work is mostly
   - [ ] Outdoor work at sea areas
   - [ ] Outdoor work at lake areas
   - [ ] Indoor work
9. The physical level of your work is mostly:

- Light work, sitting, manual work
- Mostly light work, sitting, handling heavier objects
- Light work, standing, moving, no heavy work phases, no handling or lifting heavy objects
- Intermediate work, moving, moving, bending, carrying objects, walking, walking on stairs
- Heavy work, standing, walking, lifting and carrying heavy objects
- Very heavy work, continuous heavy work movements

10. How much the following physical work environment factors cause problems to you?

<table>
<thead>
<tr>
<th>No problems</th>
<th>Some problems</th>
<th>A lot of problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold work environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind, draft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture, wetness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture to the feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture to the hands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm work environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insufficient lighting, reflections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oils, acids, chemicals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dust</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smells, gases</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11. Do you sweat during the workday?

- Yes
- No

12. How many hours do you stay outdoors weekly at work or leisure time?

<table>
<thead>
<tr>
<th>At work, h/week</th>
<th>In leisure time, h/week</th>
</tr>
</thead>
<tbody>
<tr>
<td>In fall</td>
<td></td>
</tr>
<tr>
<td>In winter</td>
<td></td>
</tr>
<tr>
<td>In spring</td>
<td></td>
</tr>
<tr>
<td>In summer</td>
<td></td>
</tr>
</tbody>
</table>
13. What kind of cold are you exposed to?

<table>
<thead>
<tr>
<th>Cold air</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling of cold materials or objects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Adverse effects caused by cold**

14. Has cold caused any of the following problems to you during last year?

<table>
<thead>
<tr>
<th>Cold has caused performance degradation in work</th>
<th>No</th>
<th>Some problems</th>
<th>A lot of problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unpleasant cold sensations cause distraction in work</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold decreases the work motivation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

15. In your opinion, does cold increase risk for occupational accidents?

<table>
<thead>
<tr>
<th>No</th>
<th>Yes</th>
<th>I do not know</th>
</tr>
</thead>
</table>

16. Has cooling caused you a clear health or performance problem in any of the following body parts?

<table>
<thead>
<tr>
<th>Face</th>
<th>Ears</th>
<th>Respiratory tract</th>
<th>Neck and shoulders</th>
<th>Shoulder and arm joints</th>
<th>Hands</th>
<th>Fingers</th>
<th>Legs, calves</th>
<th>Hip and knee joints</th>
<th>Feet, ankles</th>
<th>Toes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A lot of problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
17. Description of work: Please name and describe your three work tasks, in which you have had problems caused by cold. Name the specific problems and the issues which work well in those work tasks.

1

2

3

Cold-related symptoms and sensations

18. What kind of symptoms or sensations you have in cold?

<table>
<thead>
<tr>
<th>Cold-related symptoms</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold causes discomfort</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold causes pain in fingers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold causes pain in toes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold causes pain in face</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold-related, strong shivering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hands and / or feet cool very easy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fingers are exceptionally sensitive to cold</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

19. Which of the following symptoms you have in warm and / or in cold?

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>In warm conditions</th>
<th>In cold conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watery rhinitis</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Fingers get white</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Urticaria</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Whizing breath</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Shortage of breath</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Rhythm disturbances</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Chest pain</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Back pain</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Muscles are aching</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Joint pain in arms and legs</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Prostatitis</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Frostbites

20. Have you ever had a frostbite with a blister, ulcer or necrosis?
   - [ ] No
   - [ ] Yes

21. Have you had a frostbite in the last year?

<table>
<thead>
<tr>
<th>No</th>
<th>A slight frostbite</th>
<th>A frostbite with a blizzard</th>
<th>Number of frostbites</th>
</tr>
</thead>
<tbody>
<tr>
<td>In work</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In leisure time</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

22. Did you get the frostbite by touching cold objects?

<table>
<thead>
<tr>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>In work</td>
<td></td>
</tr>
<tr>
<td>In leisure time</td>
<td></td>
</tr>
</tbody>
</table>

23. Have you had problems from those frostbites?

<table>
<thead>
<tr>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary</td>
<td></td>
</tr>
<tr>
<td>Permanent</td>
<td></td>
</tr>
</tbody>
</table>

24. Have you changed your outdoor activities, practices or clothing because of the frostbites?

<table>
<thead>
<tr>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor work practices</td>
<td></td>
</tr>
<tr>
<td>Outdoor sport habits</td>
<td></td>
</tr>
<tr>
<td>Outdoor clothing</td>
<td></td>
</tr>
</tbody>
</table>
Clothing, personal protective devices and equipment at work in cold season

25. Choose the outerwear, which you have used mostly in the work in the last winter season in different ambient temperatures (you may choose several).

<table>
<thead>
<tr>
<th>Outerwear</th>
<th>0°C</th>
<th>-10°C</th>
<th>-20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>One piece winter coverall with thick lining</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter jacket and trousers or salopettes with thick lining</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter overall with light lining</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter jacket and trousers or salopettes with light lining</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coverall without lining</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jacket and trousers or salopettes without lining</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other set of clothing, which?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

26. Choose the intermediate wear and underwear, which you have used mostly in the work in the last winter season in different ambient temperatures (you may choose several).

<table>
<thead>
<tr>
<th>Intermediate wear and underwear</th>
<th>0°C</th>
<th>-10°C</th>
<th>-20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-sleeved cotton underwear</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-sleeved mixed fiber underwear</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-sleeved synthetic fiber underwear (so called thermal or sports underwear)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate clothing made of wool, fleece or pile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate wear made of cotton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tights and sweater or similar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other set of clothing, which?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
27. Do you need or use personal protective devices or other personal equipment?

<table>
<thead>
<tr>
<th>Equipment</th>
<th>No need to use</th>
<th>Use</th>
<th>Would need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety helmet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protective gloves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye protection device, goggles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory protective device</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hearing protective device</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety shoes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee protectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platform for standing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spot heater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety harness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other, which?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

28. Please evaluate, how well the protective clothing which you usually wear in cold season, protect you against various physical work environment risk factors.

<table>
<thead>
<tr>
<th>Environment</th>
<th>Well</th>
<th>Usually rather well</th>
<th>Poorly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Against cold air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Against wind</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Against wet snow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Against water splashes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Against dirt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Against mechanical hazards</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

29. Is the water vapor permeability (breathability) of your protective clothing sufficient?

- No
- Most of the time
- Yes
30. Does the protective clothing hinder some of the work tasks?

<table>
<thead>
<tr>
<th>Activity</th>
<th>No</th>
<th>Hinders sometimes</th>
<th>Hinders a lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stretching the arms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual tasks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotation of the torso</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bending</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating machinery or technical devices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climbing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeing, hearing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other tasks and movements, which?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

31. Does the cold make the use of the personal protective devices more difficult?

No

Yes

If yes, please specify how: _______________________________

32. Has there been improvement in the cold protective clothing provided to you in the last 4 years?

No

Yes

If yes, please specify what kind of improvements: ____________________
Cold risk prevention and management activities

33. Have there been improvements in the cold risk prevention / management activities in your workplace in the last 4 years? How were the activities started? Have you had any benefit from those activities?

<table>
<thead>
<tr>
<th>Activities</th>
<th>No increased / improved activities</th>
<th>Have not helped but they increased</th>
<th>Have helped</th>
</tr>
</thead>
<tbody>
<tr>
<td>activities started by the occupational safety personnel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>activities started by the occupational health care personnel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>activities started by the cold work project</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>new cold protective clothing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>technical improvements</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How the improvements have helped you? ____________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________

34. I need more information about the effects of cold

<table>
<thead>
<tr>
<th>Effect</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>On my health and performance in cold season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On safe sports and outdoor activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>To improve the occupational safety in my own work</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thank you for your answers!
Appendix 4 Follow-up survey: The experiences and activities after the Cold work project at the Finnish Maritime Administration

Interview form

Name: ____________________________________________
Position: _________________________________________
Maritime district and unit: ___________________________

1. Do you know that a Cold Work development project was carried out at FMA in 1999–2001?
   Yes ☐
   No ☐

2. Did you participate in the projects’
   Questionnaire survey? ☐
   Training sessions? ☐
   Workplace assessments? ☐
   Trials? ☐
   Workshops? ☐
   Otherwise, how?
   No, I did not participate ☐

How else did you participate in the project?
______________________________________________________________________________

3. Did you see the cold work as an important issue?
   Very important ☐
   Important ☐
   Not so important ☐
   Not at all important ☐
Please evaluate the process and results of the cold work project.

4. The questionnaire survey in 2000:
   - [ ] Produced a lot of new knowledge about cold-related problems at FMA
   - [ ] Produced some new knowledge about cold-related problems at FMA
   - [ ] Produced no new knowledge

5. Was the personnel informed about the cold work project
   - [ ] Well informed
   - [ ] They received some information
   - [ ] They were not informed at all

6. Did you find the training sessions
   - [ ] Useful?
   - [ ] Rather useful?
   - [ ] Not useful at all?
   - [ ] I did not participate in the training sessions

7. Did you get new information at the training sessions?
   - [ ] A lot of new information
   - [ ] Some new information
   - [ ] Not at all
   - [ ] I did not participate in the training sessions

8. Have you seen / read the FMA's Guide to Cold Work?
   - [ ] I have received the guide booklet
   - [ ] I have read it in the internet
   - [ ] I have not read it

9. To you, the cold guide booklet contained:
   - [ ] A lot of new knowledge
   - [ ] Some new knowledge
   - [ ] No new knowledge

10. Did you get new ideas in your team from the cold work project?
    - [ ] A lot of new ideas
    - [ ] Some new ideas
    - [ ] No new ideas
11. Did you get new advises or measures yourself?

- For clothing
- For other cold protection measures
- For planning the work
- For other cold-related issues, please specify below:

Which parts of the cold work project were successful?

12. The questionnaire survey
13. The workplace assessments and interview
14. The training campaign / sessions
15. The FMA’s Guide to Cold Work
16. The action model and recommendations

17. Why?

Which parts of the cold work project were incomplete or unsuccessful?

18. The questionnaire survey
19. The workplace assessments and interview
20. The training campaign / sessions
21. The FMA’s Guide to Cold Work
22. The action model and recommendations

23. Why?
Please evaluate the cold risk management activities that have happened at FMA after the Cold Work Project.

24. What kind of measures or activities have been taken to manage cold-related risks in your team or by some other actor after the cold work project? Please evaluate also if the activities have been beneficial.

<table>
<thead>
<tr>
<th>Measures / activities in:</th>
<th>Measures</th>
<th>The effects of the measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>What has been done? Who has carried out the activities? (OS, OHC, the employer, maritime district, your team, yourself…)</td>
<td>effects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a lot</td>
</tr>
<tr>
<td>a in risk assessments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b in occupational safety activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c in work planning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d in procurement of tools etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e in procurement of protective clothing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f in procurement of gloves and shoes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g in training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>h in information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i in other practices, which?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What kind of changes have happened?

____________________________________________________________________________________

____________________________________________________________________________________

In your mind, why there have not been changes in some of the recommended activities?

____________________________________________________________________________________

____________________________________________________________________________________
25. Has the cold work been taken into consideration in your occupational health care (OHC) services after the project?

- Yes
- No
- I have not used OHC services after the project

26. Please evaluate your own contribution to the project (how did you participate, how much did you use time, what was your role in achieving the project results etc.)

________________________________________________________________________

________________________________________________________________________

27. Any other comments or ideas about use of project results in the future?

________________________________________________________________________

________________________________________________________________________
Original articles


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Original articles are not included in the electronic version of the dissertation.
320. Komulainen, Mikko (2009) Bandwidth enhanced antennas for mobile terminals and multilayer ceramic packages
322. Liedes, Toni (2009) Improving the performance of the semi-active tuned mass damper
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SAFETY, HEALTH AND PRODUCTIVITY OF COLD WORK

A MANAGEMENT MODEL, IMPLEMENTATION AND EFFECTS