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Global Estimates of Occupational Accidents and Fatal Work-Related Diseases

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ERRATA

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ABSTRACT

Recording occupational accidents and occupational diseases is one of the central demands for good occupational health and safety. Western industrial countries have already for a long time recorded their occupational accidents and occupational diseases, but the established practices of recording differ from country to country. In many developing countries the recording of occupational accidents and diseases has only recently been established or is still absent. Variation in recording due to, e.g. differences in definitions and branch of compensation system is challenging in terms of understanding recorded cases. In addition, work-related diseases are typically excluded from the recording system. Work-related diseases are diseases caused by work, at least partly, but not classified as occupational diseases. For example, musculoskeletal disorders, mental diseases and occupational cancers have received increasing interest.

Occupational accidents and work-related diseases are a worldwide problem. They cause a lot of suffering and losses for the individual, organisation, community and society. Statistics of occupational accidents and work-related diseases are needed for prevention work at the enterprise and nation level. Statistics help to focus on specific areas and affect political decision-making. Especially increasing awareness in developing countries and directing limited resources to the right places is easier.

The objective of this doctoral thesis was to develop models to estimate the global number of occupational accidents and fatal work-related diseases. The study was done in three parts: the initial study and two update studies. The first one was carried out in 2001-2002. It concentrated on creating a model to estimate the number of occupational accidents for the year 1998 and fatal work-related diseases for the year 2000. The second (2003-2004) and the third (2005-2006) studies were more like update studies. The methods used in these update studies were the same as in the first study to keep the estimated numbers comparable. The number of occupational accidents was calculated for the years 2001 and 2003 as well as the number of fatal work-related diseases for the year 2002. In the second update study fatal work-related diseases figures were given for the first time by country level.

In the world approximately 2.3 million deaths occur every year because of occupational accidents and work-related diseases. It means that over 6,000 workers die every day because of their work. There were 330 million non-fatal accidents causing at least four days absence from work during one year. Deaths have remained quite the same during a five year

period, but non-fatal accidents increased by 20% in the same time period. Even though the total number of occupational accidents has increased, the fatality rate (number of fatal occupational accidents per 100 000 workers) has decreased in the same period. However, in many developing countries the amount of total employment was missing and instead the number of economically active people was used to calculate the fatality rate, which has the effect of decreasing it.

In the case of the work-related diseases it seems that work causes a lot of cancer, circulatory diseases, communicable diseases and occupational accidents. Communicable diseases are mainly a problem in developing countries, while work-related cancers are a quite big part of all cancers discovered in developed countries. Communicable diseases are expected to decrease and work-related cancers and circulatory diseases to increase in developing countries during the process of their industrialization.

Although the main objective was the creation of estimation models, several other study questions came up during the study, which affect the main objective. Two special questions were taken into more detailed review: (1) the effect of globalization on occupational accidents, and (2) the effect of competitiveness on occupational safety. The former was based on a literature review and the latter was studied by means of a simple statistical test.

From the global perspective, changes in social structure such as corporation mergers outsourcing and production flow to developing countries have impacted both in developed and developing regions on the number of occupational accidents and work-related diseases, even if this is difficult to demonstrate. Though extensive industrialization causes work-related accidents and diseases, it also increases consciousness of occupational safety and health issues. Another motivation aspect for developing countries is that better safety and health increases competitiveness. Competitiveness requires political and economic stability, as well as a well-trained labour force. Workers' awareness has increased and this usually leads to an improvement in occupational safety and health. Both at national and company level investment in safety and health decreases the number of occupational accidents and work-related diseases, but increases, e.g. the employees' job satisfaction, commitment to the company and productivity.

KEY WORDS: Occupational accidents, work-related diseases, global, estimate

TIIVISTELMÄ

Sattuneiden työtapaturmien ja todettujen ammattitautien tilastointi on yksi keskeinen vaatimus hyvälle työturvallisuustyölle. Läntiset teollisuusmaat ovat jo pitkään tilastoineet sattuneet työtapaturmat ja ammattitaudit, mutta tilastointikäytännöt vaihtelevat. Kehittyvien maiden työtapaturmien ja ammattitautien tilastointi on vasta alkamassa tai puuttuu vielä kokonaan. Haastetta työtapaturmien ja ammattitautien tilastoinnille aiheutuu raportointijärjestelmän lisäksi myös määritelmien ja hyväksymiskriteerien kautta. Eri mailla on usein erilaiset määritelmät työtapaturmalle ja ammattitaudille. Tilastoinnin ulkopuolelle jää myös työhön liittyvien sairauksien tilastointi. Ne ovat sairauksia, jotka ovat aiheutuneet töistä ainakin osittain, mutta niitä ei ole luokiteltu ammattitaudeiksi. Erityisesti tuki- ja liikuntaelimistön sairaudet, verenkiertoelimistön sairaudet ja mielenterveyden ongelmat ovat viime vuosina kasvaneet ja näkyvät työelämässä ja ennenaikaisena eläköitymisenä.

Työtapaturmat ja työhön liittyvät sairaudet ovat maailmanlaajuinen ongelma. Ne aiheuttavat paljon kärsimyksiä ja menetyksiä yksilölle, yhteisölle ja yhteiskunnalle. Tietoa työtapaturmien ja työhön liittyvien sairauksien lukumääristä tarvitaan, jotta yritykset ja yhteiskunta pystyvät suuntaamaan toimintaansa ja valitsemaan erilaisia työturvallisuuden painopistealueita toiminnan kehittämiseksi ja parantamiseksi. Valtakunnallisella tasolla työtapaturmien ja työhön liittyvien sairauksien tilastointi vaikuttaa myös poliittiseen päätöksentekoon.

Väitöskirjan tavoitteena oli luoda laskentamallit, joiden avulla pystytään maailmanlaajuisesti määrittämään työtapaturmien ja työhön liittyvien sairauksien lukumäärät. Tutkimuksessa tarkasteltiin erikseen työtapaturmia ja kuolemaan johtaneita työhön liittyviä sairauksia.

Väitöskirjatutkimus jakautuu kolmeen erilliseen osatutkimukseen, joista ensimmäinen toteutettiin vuosien 2001–2002 aikana. Tutkimus keskittyi laskentamallien luomiseen ja edelleen lukumäärien laskemiseen vuodelle 1998 työtapaturmien osalta ja vuodelle 2000 työhön liittyvien sairauksien osalta. Toinen (2003–2004) ja kolmas (2005–2006) osatutkimus olivat luonteeltaan päivitystutkimuksia. Päivitystutkimuksien menetelmät olivat samat, lukuun ottamatta pieniä korjauksia laskentamalleihin, kuin ensimmäisessä tutkimuksessa, jotta luvut pysyisivät vertailukelpoisina. Työtapaturmien lukumäärät laskettiin vuosille 2001 ja 2003 sekä työhön liittyvät sairaudet vuodelle 2002. Toisen tutkimuksen aikana myös työhön liittyvien sairauksien osalta tutkimusta laajennettiin siten, että laskettiin maakohtaiset luvut.

Tulokset osoittavat, että työtapaturmista ja työhön liittyvistä sairauksista aiheutuu vuosittain noin 2,3 miljoonaa kuolemantapausta, mikä tarkoittaa sitä, että yli 6 000 työntekijää kuolee päivittäin töiden vuoksi. Vähintään neljän päivän työkyvyttömyyden aiheuttavia työtapaturmia

sattuu noin 330 miljoonaa vuosittain. Työtapaturmien ja työhön liittyvien sairauksien aiheuttamat kuolemantapausten määrät ovat pysyneet suunnilleen samana viiden vuoden aikana, mutta vähintään neljän päivän työkyvyttömyyden aiheuttaneet työtapaturmat ovat kasvaneet merkittävästi eli noin 20 % viiden vuoden aikana. Vaikka tapaturmat määrällisesti ovat kasvaneet, tapaturmasuhde on laskenut. Tapaturmasuhdetta ei kuitenkaan voi tässä tutkimuksessa pelkästään tarkastella, koska useilta lähinnä kehittyviltä mailta puuttui tieto työllisistä ja laskelmissa on käytetty sen asemasta työvoimatietoa. Tämä laskee tapaturmasuhdetta.

Työhön liittyvien sairauksien osalta eniten kuolemantapauksia aiheuttavat syövät, sydän- ja verisuonitaudit sekä tartuntataudit. Tartuntataudit ovat lähinnä ongelmana kehittyvissä maissa, kun taas työperäinen syöpä on merkittävä syövän aiheuttaja teollistuneissa maissa. Odotettavissa on, että tartuntataudit tulevat laskemaan työolojen parantuessa myös kehittyvissä maissa, mutta toisaalta työperäiset syövät ja sydän- ja verisuonitaudit lisääntyvät maiden teollistuessa. Saadut tulokset kasvattavat toivottavasti kehittyvien maiden tietoisuutta työturvallisuudesta ja –terveellisyydestä sekä ohjaavan vähäisiä resursseja oikeisiin kohteisiin.

Vaikka tutkimuksen päätavoitteena oli tuottaa laskentamallit, nousi tutkimusten aikana esille useita erillisiä kysymyksiä, joista kaksi tutkimuskysymystä otettiin tarkempaan tarkasteluun: (1) globalisaation vaikutus työtapaturmiin sekä (2) kilpailukyvyn vaikutus työtapaturmiin ja edelleen työturvallisuuteen. Ensimmäistä tarkasteltiin kirjallisuuden valossa ja jälkimmäistä yksinkertaisilla tilastollisilla testeillä.

Kansainvälisestä näkökulmasta tarkasteltuna muutokset yhteiskunnallisessa rakenteessa kuten yhtiöiden fuusioituminen, alihankinnan lisääntyminen ja tuotannon siirtäminen kehittyviin maihin on vaikuttanut työtapaturmien ja työhön liittyvien sairauksien määriin, vaikka sitä on vaikea osoittaa puutteellisen tilastoinnin vuoksi. Varsinkin kehittyville maille työterveyteen ja turvallisuuteen panostaminen on kannattavaa kilpailukyvyn paranemisen takia. Niissä maissa, jossa kilpailukyky on hyvä, myös kuolemaan johtaneet työtapaturmat ovat matalammalla tasolla. Hyvä kilpailukyky vaatii kuitenkin poliittista ja taloudellista vakautta sekä koulutettua työvoimaa. Työntekijöiden tietoisuuden lisääntyminen parantaa myös työterveyttä ja -turvallisuutta. Sekä yhteiskunnallisella tasolla että yritystasolla panostus työterveyteen ja -turvallisuuteen vähentää työtapaturmien ja työhön liittyvien sairauksien määrää, mutta toisaalta lisää työtyytyväisyyttä ja tuottavuutta sekä sitoutumista yritykseen tai organisaatioon.

AVAINSANAT: Työtapaturma, työhön liittyvä sairaus, maailmanlaajuinen, arvio

PREFACE

My doctoral thesis was like a triathlon which includes three parts done quite separately: three research projects done for the International Labour Organization (ILO), six scientific review articles and the summary of my thesis. The time I used to this academic triathlon was not the world record, partly because I used time also for interesting bypaths. These bypaths helped me better to understand the general view of the theme and to assess methods and results.

I would like to thank Professor Kaija Leena Saarela for guiding and supporting me during this process. Especially I am grateful for Kaija Leena that she trusted me and gave me the most interesting research I have ever done and which I have not yet get tired. I am also grateful for Dr., Docent Jukka Takala who gave this project for our unit, who supervised and supported me during this long process. Dr., Docent Hannu Tarvainen and Dr. Tuula Räsänen I would like to thank for the time they used to examine this thesis and ensured that the demands of the doctoral thesis are fulfilled.

I have had in luck to work on an environment, where I have met such nice people. I would like to thank my present and former colleagues. Especially discussions with Professor Jouni Kivistö-Rahnasto, Ms. Noora Nenonen M.Sc., Ms. Sanna Nenonen M.Sc. and Mr. Pertti Palukka M.Sc. have taken my work forward. What would I have done without Ms. Heli Kiviranta during these years; thank you for everything.

I would like to acknowledge the ILO department of Programme on Safety and Health at Work and the Environment (SAFEWORK), Academy of Finland and Tampere University of Technology for funding. I would also like to thank the Finnish Work Environment Fund for giving me a scholarship which gave me the possibility to work as a part time and wrote articles. Also financial support from Finnish Doctoral Program in Industrial Engineering and Management gave me possibility to write summary and finalise my thesis.

I would like to thank my parents Maija and Jarke, my sister Outi and my brother Pete. They trusted me and brought me down to earth. They also taught me that I cannot always be right. My loving thanks for my husband Jari, who always knew that I got this thesis ready even it took time. My daughter Siiri and sons Eero and Aapo, now it is over.

LIST OF ORIGINAL PAPERS

This doctoral thesis consists of six papers based on a study performed during the years 2001-2006. Four of the six papers were written with co-authors and five of them have been published or accepted to be published in scientific journals in the field of safety and health. One paper has been presented in a peer review conference and has been published in the proceeds of the conference. The papers are referred to in the text by Roman numerals.

I Hämäläinen P, Takala J, Saarela KL. 2006. Global estimates of occupational accidents. Safety Science 44:137-156.

II Hämäläinen P, Takala J, Saarela KL. 2007. Global estimates of fatal work-related diseases. American Journal of Industrial Medicine 50:28-41.

III Hämäläinen P. 2009. The effect of globalization on occupational accidents. Safety Science 47:733-742

IV Hämäläinen P, Saarela KL, Takala J. 2009. Global trend according to estimated number of occupational accidents and fatal work-related diseases at region and country level. Journal of Safety Research 40:125-139.

V Hämäläinen P, Saarela KL, Takala J. Fatal work-related diseases – global estimates. International Journal of Occupational and Environmental Medicine (Evaluation of the latest round of changes is in process)

VI Hämäläinen P. 2007. The effect of competitiveness on occupational safety. In: Helander M, Xie M, Jiao R, Tan KC (ed). Proceedings of the IEEE International Conference on Industrial Engineering and Engineering Management IEEM2007, December 2-5, 2007, Singapore. CD-ROM, ISBN 1-4244-1529-2.

Paper I gives the number of global estimates of occupational accidents which are based on an estimation model created in the study. The model is described in Paper I. Paper II presents global estimates of fatal work-related diseases and the model created for estimates. Paper III gives updated estimates of occupational accidents, but also considers the effect of globalization on occupational safety and health. Paper IV presents a corrected model of estimation of occupational accidents as well as updated estimates of occupational accidents and fatal work-related diseases at the country level. Paper IV also summarises estimates made during the study period. Paper V gives updated estimates of fatal work-related diseases by disease group and gender. Paper V describes the correction done for the model

and summarises the estimates made for two separate years. Paper VI describes occupational safety from the competitiveness point of view.

Päivi Hämäläinen is the first author and had the main responsibility for the papers. Table I below presents the author's contribution.

Table I. Author's contribution to the papers

Paper	Contribution to paper
I Global estimates of occupational accidents II Global estimates of fatal work-related diseases	Study design Data collection Creating the model to estimate the number of occupational accidents and fatal work-related diseases Calculating estimates Main responsibility for writing the papers
III The effect of globalization on occupational accidents	Data collection Literature review Writing the paper
IV Global trend according to estimated number of occupational accidents and fatal work-related diseases at region and country level V Fatal work-related diseases – global estimates	Data collection Making changes to methods Calculating estimates Main responsibility for writing the paper
VI The effect of competitiveness on occupational safety	Data collection Making analyses Writing the paper

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KEY DEFINITIONS

Accident	Undesired event giving rise to death, ill health, injury (BS 8800:2004)
Attributable fraction	The proportion of cases among the exposed that could have been prevented if they had never been exposed (dos Santos Silva 1999 p.98).
Competitiveness	The set of institutions, policies, and factors that determine the level of productivity of a country. The concept of competitiveness involves static and dynamic components. (Sala-I-Martin et al. 2009 p. 4)
Competitiveness index (CPI)	A weighted average of different components grouped into pillars (Sala-I-Martin et al. 2009 p. 4).
Globalisation	The process by which businesses or other organizations develop international influence or start operating on an international scale (The Oxford Dictionary of English (2nd edition revised) 2005)
Occupational accident	An occurrence arising out of or in the course of work which results in: (a) fatal occupational injury; (b) non-fatal occupational injury (Recording and notification... 1996 p. 3 ILO).
Occupational disease	A disease contracted as a result of an exposure to risk factors arising from work activity (Recording and notification... 1996 p. 3 ILO).
Occupational injury	Death, any personal injury or disease resulting from an occupational accident (Recording and notification... 1996 p. 3 ILO).
Work-related disease	Multi-factorial diseases among a working population, which are partly caused by work, and/or aggravated, accelerated or exacerbated by occupational exposures, and/or the cause of impaired work capacity (Weevers et al. 2005).

1. INTRODUCTION

1.1 Work and health

Work is one of the central elements in peoples' life. Work gives safety and security and also makes life meaningful. However, work can also affect workers' health in many ways. The effects on health may be positive like feeling that you are doing something important and are a member of working society, but work may also cause negative impacts like occupational accidents and work-related diseases.

Occupational accidents and occupational diseases have been of interest in many countries for over a hundred years. Mainly industrialized countries have prescribed different laws and regulations to prevent occupational accidents and occupational diseases and to protect workers from them (Spreeuwer 2008 p. 7, 9). These countries especially have monitored occupational accident levels. During recent decades countries and companies have become more and more interested in occupational accidents and this is at least partly because of the cost of accidents. Also work-related diseases caused by work, but not classified as occupational diseases, have received more interest in recent years. The International Labour Organization (ILO) has estimated that the total costs of occupational accidents and work-related diseases are 4% of the gross national product (GNP) (Safety in numbers 2003 p. 15). The total GNP of the world was approximately $34 * 10^{12}$ USD in 2003 (Statistics Finland 2005), which means that worldwide the annual cost of work-related injuries and diseases is approximately $1.36 * 10^{12}$ USD.

Work-related diseases are an increasing problem that countries are just becoming aware of. Recent studies have shown that the number of work-related diseases seems to be underestimated (Driscoll et al. 2005a; Nelson et al. 2005; Steenland et al. 2003), for example in the case of work-related cancers (Driscoll et al. 2005b; Morrell et al. 1998; Park et al. 2002; Zahm and Blair 2003), musculoskeletal disorders (Punnett et al. 2005), respiratory diseases (Driscoll et al. 2005c; Leigh et al. 1997), psycho-social problems, and circulatory diseases (Leigh et al. 1997; Nurminen and Karjalainen 2001).

In companies, preventative activities focus more often on occupational accidents than on work-related diseases. This can be seen in the faster decrease in accident rates. Work-related diseases often have a long latent period (Nelson et al. 2005; Nurminen and Karjalainen 2001) and might be the result of different work-related factors like working time (Caruso et al. 2006) and work-load (Hamet and Tremblay 2002; Åkerstedt et al. 2004). Exposures occurring now usually lead to ill health in the future. This is because either the

level of exposure is underestimated or unknown or the risk posed by exposures (single or combination) is not properly recognized. (Driscoll et al. 2005a; Morrell et al. 1998)

The proportion of traditional occupational accidents from all work-related hazards is decreasing in more developed countries, where workers are working and living longer (Driscoll et al. 2005a; Punnett et al. 2005). At the same time, the number of occupational accidents and work-related diseases is growing in developing countries. The number of occupational accidents and work-related diseases is needed because reliable official figures are missing or lacking. Lack of published data is the case also in many developed countries, and for developing countries this information is usually missing. Some estimates of occupational accidents for developing countries can be found, but usually they are based on information obtained from developed countries. However, work-related morbidity and mortality cannot easily be calculated (Driscoll et al. 2005a). Also cultural and structural differences between countries complicate the global estimation of occupational accidents and work-related diseases (Concha-Barrientos et al. 2005; Nelson et al. 2005).

Increasing globalisation has affected occupational safety. The flow of industrial production to developing countries has increased and the increase is still continuing. Occupational accidents are on the decrease in developed countries and increasing in developing countries because production work is usually the most dangerous. Also, the demand for effectiveness and mergers has decreased occupational accidents in developed countries. Quite often, occupational safety work is justified by increased productivity. ILO has shown that the most competitive countries are also the safest (Decent work... 2005 p. 14).

1.2 Global estimates

The first global estimates of occupational accidents and work-related diseases were published by Takala (1999) and Leigh et al. (1999). Takala (1999) estimated that annually 1.1 million work-related deaths happen, comprising occupational accidents, commuting accidents, and occupational and work-related diseases. Leigh et al. (1999) estimated that approximately 100,000,000 occupational injuries and 700,000 fatal occupational diseases happen annually. Newer global estimates have been published by Concha-Barrientos et al. (2005). They estimated that annually approximately 312,000 fatal unintentional occupational injuries happen. However, the estimates give the total number of occupational accidents and work-related diseases - country based estimates are not given.

The doctoral thesis presented here is based on a study carried out in co-operation with the International Labour Organization (ILO) at the Center for Safety Management and Engineering (formerly the Institute of Occupational Safety Engineering), Tampere University of Technology (TUT), Finland. The study was carried out during the years 2001-2006 and ILO supported the study financially. The main objective was to develop models to estimate

the number of global occupational accidents and fatal work-related diseases at the region and country level.

2. LITERATURE REVIEW

2.1 Occupational accidents

2.1.1 Concept of occupational accident

The meaning of accident has varied over time. In the beginning of human development accidents were thought of as being from the gods (Grimaldi and Simonds 1984 p. 27; Hale 2003 p. 330; Kjellén 2000 p. 3; Loimer et al. 1996). They were mostly causes of nature or connected to them. Occupational accidents – as we now understand them – are linked to work. Before the Industrial Revolution accidents were rare occurrences, usually involving workers and not outside people (Heinrich 1959 p. 423). In the beginning of the Industrial Revolution the number of accidents increased: occupational accidents and deaths were frequent (Anton 1989 p.372-376; Loimer et al. 1996) At the same time, the nature of accidents changed: accidents were more serious and also injured or killed persons who were not directly connected to the working situation (Kjellén 2000 p. 3).

Even though accident is a simple word the meaning of it varies in different contexts (Harms-Ringdahl 2001 p. 13). Accident is a wider concept than occupational accident, which is only one type of accident (Heinrich 1959 p. 3). Accident is something a person does not usually think about, but the possibility of it is present (Hollnagel 2004 p. 3). Accident is a word which has many meanings, depending on the context. Accident can be, e.g. occupational accident, industrial accident, (occupational) injury, traffic accident, home and leisure accident. In the safety field an accident is typically understood as an occurrence which leads to injury (Heinrich 1959 p. 3), or other loss and harm (Hollnagel 2004 p. 5).

According to Reason (1997 p. 1), there are two types of accident: individual accidents and organizational accidents. Individual accidents are more common, while organizational accidents are comparatively rare, but often catastrophic. Organizational accidents are events which occur within complex modern technologies and have multiple causes. In an individual accident the person is typically both the agent and the victim of the accident. (Reason 1997 p. 1) Nevertheless, accidents have been defined in several ways. Taylor (1976) divided different definitions into four classes, as follows:

1. Definition by consequence: occupational accident statistics are usually based on this definition.
2. Definition by antecedent: previous events are defined.
3. Definition by intention: objectives and motives of the action are defined.
4. Definition by justification: usually there is an attempt to find the causes or person who is responsible for the accident. Based on judicial operation.

Hollnagell (2004 pp. 5-6, 10) defines accident as a short, sudden and unexpected event that is directly or indirectly the result of human activity rather than, e.g. a natural event like an earthquake. An accident is short rather than slowly developing, and sudden without warning. The outcome has to be negative. Departing from the traditional description of accident, Hollnagel (2004 p. 7) includes both unexpected event and unwanted outcome as part of an accident (Figure 2.1). Typically, accident is defined as the result of an unexpected event leading to an unwanted outcome resulting from the accident.

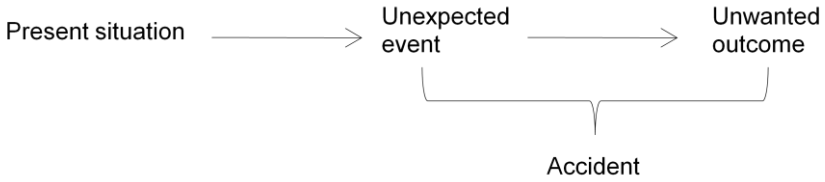


Figure 2.1. Elements of accident (modified from Hollnagel 2004 p. 7)

The literature of the occupational safety and health does not typically define the term occupational accident, it instead define term accident even when it is meaning occupational or industrial accident. Table 2.1 presents definitions for the term accident.

Table 2.1. Definitions of accident

Authors or book and year	**Definition**
The Oxford Dictionary of English (2nd edition revised) 2005	An unfortunate incident that happens unexpectedly and unintentionally, typically resulting in damage or injury
The Oxford American Dictionary of Current English 2002	An event that is without apparent cause, or is unexpected.
BS 8800:2004	Undesired event giving rise to death, ill health, injury
Heinrich 1959 p. 16	An accident is an unplanned and uncontrolled event in which the action or reaction of the object, substance, person, or radiation results in personal injury or the probability thereof.
Anton 1989 p. 2	Accident is unplanned, uncontrolled, and in some way undesirable; it disrupts the normal functions of a person or persons and causes injury or near-injury.
Hollnagel 2004 p. 4	A short, sudden and unexpected event or occurrence that results in an unwanted and undesirable outcome.
Taylor et al. 2004 p. 5	An unplanned event that may or may not result in damage, loss or injury.

An occupational accident is, in the same way as an accident, an unwanted, unplanned and uncontrolled event affecting people, the workplace and society. It is also an even which has been used as the basis for organised safety work in companies from soon after the Industrial Revolution (Grimaldi and Simonds 1984 p. 8). The term occupational accident and its meaning vary from country to country. There is no general agreement about its definition (Boyle 2003 p. 263; Loimer et al. 1996) and a definition for it is very hard to find. The Oxford Dictionary of English and the Oxford American Dictionary of Current English do not define the term occupational accident or injury. Collins English Dictionary defines occupational accident and occupational injury as synonymous. Other synonyms are: accident at work, industrial accident and workplace accident.

Quite often is thought that occupational accidents may involve several injuries and/or other harm in organizations. The International Labour Organizations (ILO) defines occupational accident as an occurrence which results in a fatal occupational injury and/or non-fatal occupational injury. This definition thus includes only personal injury as a part of occupational accident. The definition does not include other losses. Definitions can also be found where occupational injury is understood as a wider concept than occupational accident (Andersson p. 17). Harms-Ringdahl (2001 p. 13) suggests that occupational injuries can occur in a variety of ways. According to him, occupational injuries can be divided into three categories:

1. Occupational accidents – accidents occurring in the workplace.
2. Occupational disease – harmful effects of work that are not due to an accident, such as over-exertion injuries, allergies or hearing complaints.
3. Commuting accident – accident occurring on the way to or from the workplace.

As can be seen, in this division occupational accident is part of occupational injury and more precisely includes - as a definition of ILO - only workplace accidents. Actually, one can argue that there is no need to define occupational accidents. The same definition can be used as for the term accident. Occupational is an additional term indicating that the accident occurs at work. However, two more definitions can be found, as presented in Table 2.2.

Table 2.2. Definitions of occupational accidents

Authors and year	Definition
Recording and notification... 1996 p. 3 (ILO)	An occupational accident is defined as an occurrence arising out of or in the course of work and resulting in fatal occupational injury and/or non-fatal occupational injury.
Harms-Ringdahl 2001 p. 13	Occupational accident is meaning a sudden and unexpected event that leads to the injury of human being in the course of his or her work.

Many safety and health professionals avoid using the word accident, since its definition can be seen as a random and unpredictable event or an act of fate (Beaulne 1998). It is argued that it could weaken injury prevention efforts. In addition, the term accident is used differently in different regions. Safety and health professionals especially from North America and

Australia, are more concerned about using the word accident than, for example, professionals from Europe (Andersson 1999 p. 17; Beaulne 1998).

However, in this thesis occupational accident is understood as synonymous with occupational injury and is used interchangeably. Occupational accident indicates one injury; in other words, the total number of occupational accidents means the same as the total number of occupational injuries - fatal or non-fatal.

2.1.2 Occupational accidents: theories and models

Occupational accidents are one of the main reasons why enterprises and organizations have start prevention activities. The starting point for better safety and health in enterprises and organizations was when people changed their work from agriculture to industrial work over a hundred years ago. Quite soon after the technical revolution it became clear that new industrial work was harmful and quite often dangerous. Workers faced working conditions they were not used to and they could not understand the potential hazards (Grimaldi and Simonds 1984, p. 32). Also employers faced a new situation which was not familiar to them, but they did not necessarily think about and care so much for working conditions to the same degree that they did with profits (Anton 1989 p. 372; Grimaldi and Simonds 1984 p. 31-33; Loimer et al. 1996). It took some time before industrial safety started after the Industrial Revolution. They did not happen simultaneously (Heinrich 1959 p. 424). However, workers were activated to demand better working conditions and the first occupational laws were enacted in the 19th century (Grimaldi and Simonds 1984 p. 27-30; Hale et al. 1998 p. 2; Heinrich 1959 p. 427).

Occupational accident theories have concentrated on accident prevention. It has been a cornerstone in any safety management system in companies, and still is today (Kjellén 2000 p. 3). The development of occupational accident theories has been based on the increasing understanding of accidents and its meaning for workers, companies and society (Kjellén 2000 p. 32). The early trial and error approach has changed or should be changed to predictive risk analyses (Hollnagel 2004 p. 3; Rasmussen 1997).

Although an accident is an unwanted, unplanned and uncontrolled event, it is not inevitable (Hollnagel 2004 p. 3). When Heinrich combined separate and dispersed safety practices in the first safety theory in the 1920's, he created theory which has affected safety and health work to the present days. Heinrich created an accident model called the Domino theory, in which an accident is described as a chain of conditions and events causing injury. Heinrich (1959 p. 21) claimed that 88% of accidents were caused primarily by the dangerous actions of workers. This led to a prevention program which concentrated on human performance and human factors like better training, education and motivation for workers (Purswell and Rumar 1984).

There are several different procedures involved when accident models are divided. Andersson (1999 pp. 19-28) divided them into three categories: linear stage models, system-oriented models and meso- and macro-level approaches. Kjellén (2000 pp. 32-52) used more specific categorization, dividing accident models into six categories: causal-sequence models, process models, energy models, logical tree models, human information processing models and organizational models.

Causal-sequence models describe an accident as a chain of events that occur in certain order. The first model of this was the Chain of Multiple Events, i.e. Domino theory by Heinrich. An accident will be prevented if an unsafe act or conditions are invalidated. This model has had a lot of influenced on the development of other accident models, also on models other than causal-sequence ones. Especially the Tripod model (better known as the Swiss cheese model) by Reason (1991) has had large influence on the current understanding of accident theory and the causality of accidents. It tries to take account also of multiple causality, which was one of the main weaknesses in Domino theory (Bamber 2003 p. 200; Hollnagel 2004 p. 50). According to Reason (1991 pp. 199-212; 1997 pp. 11-13), different levels of organization may have or produce active failures and defensive weaknesses. Defensive weaknesses, also called latent conditions, are weaknesses which have developed already in the beginning of a system or they have developed unnoticed or in an uncorrected situation. When these active failures and latent conditions in different organizational levels match, an accident occurs.

In **process models,** time is the basic variable. Process models help to understand how a production system gradually declines from a normal state into a state which leads to an accident. Process models make a clear distinction between the accident sequence and the underlying causal or contributing factors. (Kjellén 2000 p. 36)

Energy models have their roots in epidemiology, which is the science of diseases in the population; in other words, all kind of illness are understood as the results of interaction between people, hazards and the environment (Andersson 1999 p. 19; Bamber 2003 p. 200; Bengtsson 1984). The injury agent is energy exchange, which can be mechanical, chemical, thermal, electrical, etc. (Haddon 1968; Kjellén 2000 p. 39). One well-known scientist, Haddon (Beaulne 1998) created a theory which has strongly influenced the understanding of accidents and safety research. Haddon thought that accidents and injuries do not deviate scientifically from other types of health disorders. He developed an approach to injury control based on epidemiological principles in the 1960s - the so-called Haddon Matrix. (Haddon 1968)

Logical tree models are mainly used in theoretical analyses to estimate the risk of injury or damage. These models aim at analyzing the causes of injury or damage in terms of the logical relation between events and conditions in the affected system. (Kjellén 2000 p. 43)

Logical tree models typically have so-called root causes, which mean that there must be a first event or occurrence that makes an accident happen. (Hollnagel 2004 p. 51)

The interaction between the human operator and the environment in a disturbed system is the main focus in **human information processing models**. The interaction is analysed from the operator's point of view and responds to deviations and hazards in the environment. Human failures are identified and evaluated to take the appropriate measures. (Kjellén 2000 p. 44)

Organisational models can be divided into two categories: safety, health and environment management models, and culture models. The basic idea behind management models is that organizations have an ideal safety and health management system. When actual conditions are compared with the ideal model, the weaknesses and gaps are identified. Typically, organizational models are based on a structural perspective on organizations. (Kjellén 2000 p. 45) Culture models focus on the variables of shared beliefs, attitudes and norms within an organization. Workers´ involvement and organisational learning are included as a part of culture models. (Kjellén 2000 p. 51)

All these models in different categories are overlapping. An individual model may belong several groups. Perhaps a more descriptive classification has been done by Hollnagel (2004). He divided models into three categories: sequential models, epidemiological accident models and systemic accident models. This division takes into consideration changes happened in society as well as the need for new understanding of accidents and the theory behind them. Table 2.3 presents the main types of accident models and the idea of how an accident analysis should be carried out and what the response should be.

Table 2.3. The main types of accident models (modified from Hollnagel 2004 p. 66)

	Sequential models	Epidemiological models	Systemic models
Search principle	Specific causes and well-defined links	Carriers, barriers and latent conditions	Tight couplings and complex interactions
Analysis goals	Eliminate or contain causes	Make defenses and barriers stronger	Monitor and control performance variability
Examples	Chain or sequence of events	Latent conditions	Control theoretic models
	Tree models	Carrier-barriers	Chaos models
	Network models	Pathological systems	Stochastic resonance

Although over time the understanding of accidents has increased and models have been developed, it does not mean that some models are unequivocally better than others (Hollnagel 2004 p. 66). Usually, it is recommended that several models be used when analyzing accidents or finding the causes of possible accidents (Harms-Ringdahl 2001 p. 224).

2.1.3 The cause of occupational accidents

Whenever something unexpected happens there is an attempt to find an explanation for it and the causes even when these do not exist. (Hollnagel 2004 p. 25) The frame of occupational accident theories has affected the concept of causes. At the beginning of the 20th century it was believed that a person by him/herself is prone to occupational accidents (Froggatt and Smiley 1964). It led to the situation where employers did not put effort into improving working conditions, but blamed the workers for causing occupational accidents themselves (Loimer 1996). In this theory occupational accidents were thought to happen to a relatively small group of workers who had the endogenous tendency to be prone to accidents (Froggatt and Smiley 1964; Grimaldi and Simonds 1984 p. 248). Accident proneness was thought to be a personality characteristic (Petersen 1996 p. 213). Occupational accidents were considered for the first time from the point of view of human factors (Hale 2003 p. 330; Salminen 1994).

At present accident proneness is considered to account for only a small part of accidents (Grimaldi and Simonds 1984 p. 249; Kjellén 2000 p. 32; Petersen 1996 p. 213). Accident proneness has been criticized widely and the criticism has culminated in questioning if persons under research have the same risk of encountering accidents (Froggatt and Smiley 1964; Salminen 1994). A preventative strategy based on accident proneness typically has only minor effects (Kjellén 2000 p. 32) and elimination of applicants for job based on their accident proneness does not seem to decrease occupational accidents (Guastello 1993).

When Heinrich presented his industrial accident theory, he placed the blame for industrial accidents mainly on dangerous acts on the part of the individual worker (Heinrich 1959 p. 13). Human factors played the main role in accident prevention. However, Heinrich (1959 p. 43) for the first time also stressed the responsibility of the employer for creating unsafe working conditions.

Focus on the causes of occupational accidents has changed over time. It has varied between the human and technical point of view, but human behavior has always been the most important part of it: sometimes people have been the problem and sometimes the guarantee of safety, as presented in Figure 2.2 (Hale 2003 p. 330).

When the system got even more complex and occupational accidents became more serious, the explanation of the human factor was not adequate. Reason (1997 p. 25) indicated that the human condition cannot be changed, but the conditions under which people are working can be changed. The focus turns onto organizational factors (Hale 2003 p. 330; Rasmussen 1997; Reason 1997 p. 1).

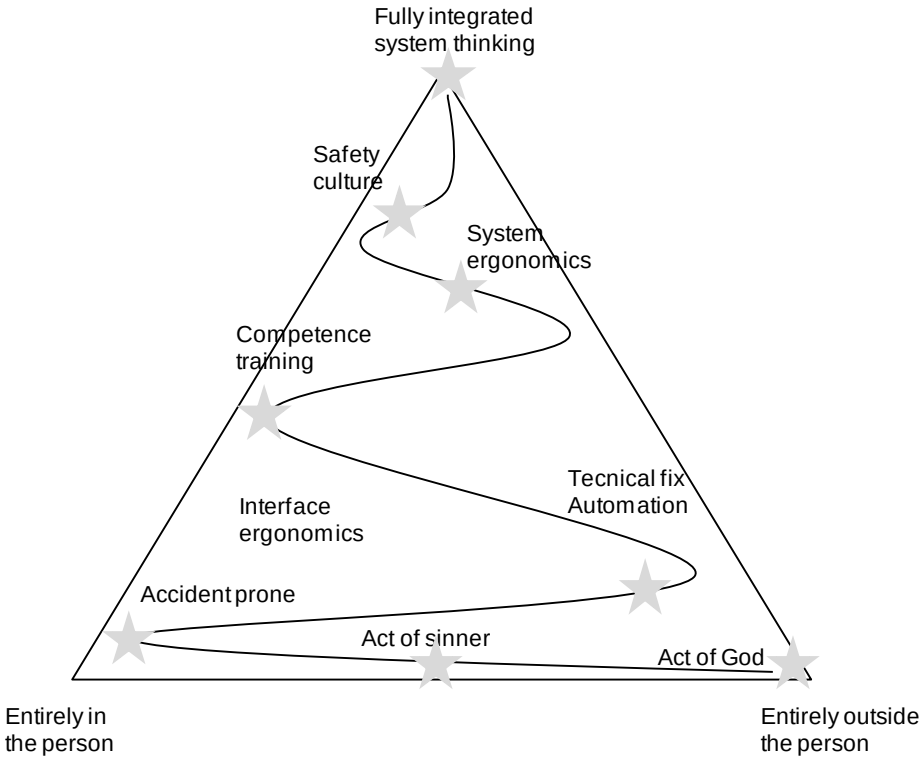


Figure 2.2. Changing view of accident causes (modified from Hale 2003 p. 331)

Wallace (1996 p. 114) presents the basic causes which may cause an accident. These are:

- personal factors,
- knowledge, training or skill,
- motivation,
- supervision,
- equipment/facility design or standards,
- maintenance and
- procedures.

According to Hollnagell (2004 pp. 34-35), the cause of an accident has the following characteristics:

- It can be associated with system structure or function like people, components, procedures, etc. The cause can be associated with something that can be concretely thought about.
- It is possible to reduce or eliminate the cause within accepted limits of cost and time.
- It conforms to the current understanding of explanations. Hollnagel (2004 p. 35) stressed that this is the most important aspect, because the search for causes stops when an acceptable one has been found. He still emphasised that an acceptable cause at one particular time may not always remain so.

“The value of finding the correct cause or explanation is that it becomes possible to do something constructively to prevent future accidents.” (Hollnagel 2004 p. 35)

2.2 Work-related diseases

2.2.1 Concept of occupational and work-related disease

In the same way as in the case of occupational accidents, occupational diseases were rare before the Industrial Revolution. After the revolution the growing concern was mainly focused on occupational accidents. Other exposures in workplaces did not receive the same importance (Anton 1989 p. 376; Grimaldi and Simonds 1984 p. 38). Very little was done to prevent occupational diseases (Coates 2003 p. 421). In the end of the 19th century poisoning by lead, phosphorus and arsenic increased. Especially poisoning by phosphorus both in Great Britain (Coates 2003 p. 422) and in the USA (Anton 1989 p. 375) came to the public attention. ILO has had a central role in the identification of occupational diseases over time (Niu 2002). In 1919 ILO declared anthrax an occupational disease and in 1925 it published the first ILO list of occupational diseases containing three diseases (Lesage 1998 p. 26.2). In 1980 a new list contained 29 occupational diseases. After that the development of diagnostic technology and epidemiology in recent decades has made it possible to identify new physical, chemical and biological factors which affect people. (Niu 2002)

Occupational diseases are a widely studied area and typically it takes several years before an occupational disease is accepted as caused by work (Coggon 2001). Exposures to different physical, chemical and biological factors have been investigated for a long time, and they are still being extensively investigated (Johnson and Lipscomb 2006; Spreeuwers 2008 p. 158). Many conventions of the International Labour Organization (ILO) focus on hazardous substances. Lists of hazardous chemicals which are known to affect workers negatively are used in many countries, and these lists give limits for the duration of different exposures (ILO 2008). However, only some of the hazardous exposures are accepted as causes of occupational disease (van Kampen et al. 2008; Niu 2002; Spreeuwers 2008 p. 9) and quite many hazardous substances are used simultaneously in the same workplaces. The combination of hazardous exposures can have different effects and also affect the worker in several ways. (Driscoll et al. 2005a; O’Neill et al. 2007) The World Health Organisation (WHO) has estimated that workers are exposed at workplaces to about 50 different physical factors, 100 000 chemical risk factors and 200 biological agents. It has also estimated that there are about 3 000 allergenic factors in our environment, most of them occurring as occupational exposures, as well as some 20 adverse ergonomic conditions. (WHO 1994)

Definitions of occupational diseases are set out in different countries’ legislation and all definitions specify causality between diseases, exposure and work (Niu 2002). ILO defines occupational disease as a disease that results from exposure to risk factors during a work

activity (Recording and notification... 1996). Work-related disease is a wider concept. It covers also occupational diseases, and they are estimated to be a much bigger problem (Driscoll et al. 2005a; Leigh et al. 1999; Nurminen and Karjalainen 2001) than official occupational disease data show (e.g. Australian Government 2008; Eurostat 2008; United States... 2008).

Weevers et al. (2005) have defined work-related disease as follows: “Work-related diseases are defined as multi-factorial diseases among a working population, which are partly caused by work, and/or aggravated, accelerated or exacerbated by occupational exposures, and/or the cause of impaired work capacity”. The definition covers diseases that have been shown to have an association with work; for example, work-related cancer, musculoskeletal disorders, psycho-social problems and circulatory diseases (Driscoll et al. 2005b; Punnett et al. 2005; Zahm and Blair 2003).

The definition of occupational disease is non-uniform (Spreeuwers 2008 p. 10) and sometimes occupational disease and work-related disease are used synonymously (Collins English Dictionary 2009). Lesage (1998 p. 26.2) categorises the relationship between work and diseases as follows:

- occupational diseases having a specific or a strong relation to occupation, typically one causal exposure
- work-related diseases whose relation is less obvious and with multiple causal agents
- diseases affecting the working population where the relation between working conditions and health effects can be demonstrated only on the population level.

In this thesis the term work-related disease covers all the definitions Lesage used. As a whole, the concepts of occupational disease and work-related disease are complicated (Spreeuwers 2008 p. 162) and have always been a matter of discussion (Lesage 1998 p. 26.2).

The relation to work can be accessed through an attributable fraction - the proportion of the disease that would not have occurred if the risk factor had not existed - in this case, related to work. (Driscoll et al. 2005ab; dos Santos Silva 1999 p.98; Nelson et al. 2005; Steenland et al. 2003; Nurminen and Karjalainen 2001).

2.2.2 The cause of work-related disease

Traditional factors that are well known causes of work-related diseases, and have been seen to have a major effect on the incidence and mortality of work-related diseases, include: hazardous substances (e.g., asbestos, silica dusts, pesticides, radon), ionizing radiation, non-ionizing radiation, noise and other physical factors (Coates 2003 p. 245). Some well-known factors that further affect and contribute to the number of work-related diseases

include: age, sex, shift work, overwork and stress, communicable diseases at work, violence at work, and child labour (Coates 2003 p. 425; Eijkemans and Takala 2005; Nakata et al. 2006). Also, worker lifestyle may contribute to the later occurrence of work-related disease (Driscoll et al. 2005a; Leigh et al. 1999).

Work-related diseases cause often serious personal suffering and the social consequences caused by sickness absence, unemployment, loss of income, the disturbance of family relations, as well as psychological and physical problems (Dembe 2001). In addition, the economic cost of occupational diseases is considerable (Spreeuwers 2008 p. 7), which indicates that the cost of work-related diseases is enormous.

The most studied area is occupational cancers, which often have a long latent period. The conservative estimation of work-related cancers has leant on the attributable fraction from Doll and Peto (1981). They estimated that the proportion of cancer deaths attributable to occupation is 4% (best estimate), the range being from 2% to 8% (Doll and Peto 1981 p. 1256) Today, there has been some criticism of their attributable fraction. The main criticism is concerned with its validity in today's world (O'Neill at al. 2007). Also, new research from Great Britain estimates the incidence of occupational cancer to be slightly greater (Rushton et al. 2008) than Doll and Peto´s (1981) figures. Ruston et al. (2008) estimated that 4.9% of deaths were attributed to work-related carcinogens for the six cancers assessed.

Occupational respiratory diseases, and especially occupational asthma, seem to be increasing (Blanc and Toren 1999; Driscoll et al. 2005c). The latter is one of the most common occupational diseases in the world (Blanc and Toren 1999; Quint et al. 2008). Research from South Africa (Jeebhay 2002) and Iran (Boskabady et al. 2007) indicates an increase in respiratory diseases, while studies made in Germany (van Kampen et al. 2008) show a decreasing trend in respiratory diseases. Blanc and Toren (1999) estimated that 9% of adult asthma is associated with occupational factors, while Driscoll et al. (2005c) estimated the figure to be 17%. Mental disorder seems to be an increasing problem, at least in industrial countries (Chatterji et al. 2007; Wang et al. 2006). For example, job strain (Choi et al. 2008) and shift work (Saijo et al. 2008; Wang et al. 2007) cause mental disorders, but these same factors are also shown to cause work-related circulatory diseases (Ha and Park 2005; Härmä et al. 2006; Johnson and Lipscomb 2006). On the other hand, the results of some studies do not support this association (Bøggild et al. 1999; Chen et al. 2007).

Work-related stress has many consequences, including an inability to do what was meant to be done and failure to meet targets (Ridley 3003 p. 643). Stress as well as shift and overwork are increasingly causing work-related diseases in the world (Caruso et al. 2004; Trinkoff et al. 2006). They may lead to sleeping disorders, which in turn, become a risk factor for high blood pressure, obesity, type II diabetes, and coronary heart disease (Härmä et al. 2006). They may also be linked to the misuse of alcohol and drugs, as well as

workplace violence (Drug and alcohol abuse 2003; Johnson and Lipscomb 2006; Kalia 2002; Kenny 2002 p. 82). Serious stress may also lead to a long period of work inability.

Workplace violence has always been present at the workplace, but the western world began to pay attention to it in the 1960s (Bowie 2002 p. 1; Kenny 2002 p. 76). Work-related violence can be caused by outsiders, customers, patients or clients, but also other staff members (Bowie 2002 pp. 6-14), and has resulted in both physical and psychological damage and even death. A part of violent incidents are included in occupational accident statistics. To prevent work-related violence, workplaces have a key position in ensuring that the threat of violence is adequately taken into account. (Hintikka and Saarela 2010) The internal reporting system provides valuable material for prevention purposes, but reliable monitoring systems are also needed for national level purposes (Saarela 2002). A reporting system is needed to develop programmes for educating and training as well as guiding the development of organisational policies at the national level (Wynne et al. 1997 p. 1).

It is estimated that 250 million children aged 5 -18 are working, and approximately 120 million of those are working full-time (Child labour... 2002 p. 6). Most child labourers work in their communities alongside their parents and siblings (Estrella-Gust 2002), mainly in agricultural activities (Child labour... 2002 p. 6). Skin, eye, respiratory and nervous problems because of pesticides, as well as chronic coughs and pneumonia, accidents and poisonous snake and insect bites are typical problems for children working in agricultural work (Child labour... 2002 p. 8). Many children are also in hazardous and exploitative jobs away from home. Work hazards affect children more seriously than adults, resulting in both physical and psychological consequences (Caesar-Leo 1999; Child labour... 2002 p. 15-16).

2.3 Safety management

Safety management has roots in high-hazard process technologies in the transport, petrochemical, and manufacturing industries (Hale et al. 1998 p. 1). It is both old and new, depending on the point of view. Hale and Hovden (1998 p. 129-131) see that the development of safety management can be divided into three phases of development. The first age started after the first factory and mining legislation when the state made obligations to protect workers. Safety was seen as a technical problem, not a managerial one. After the Second World War the second age started. There was an increasing realization that technical risk assessment and prevention measures could not answer all the problems. The study of human factors was seen as the key element in safety and health work. The third age for safety management started after increasing dissatisfaction with the idea that human error can be the main interpretative factor in safety management. Also major disasters like Chernobyl, Piper Alpha and Three Mile Island heightened the change in thinking. The third age focuses directly on the structure and functioning of management. (Hale and Hovden 1998 p. 129-131)

Safety management concerns the protection of people, the environment and assets (Visser 1998 p. 43). It is a central part of the operation in organisations which want to develop their occupational safety and health. The objective of safety management is to affect both strategic decision-making and operational action to prevent accidents and other harmful events (Lanne 2007 p. 28-29). Nowadays, safety management is a systematic method for continuous improvement.

A uniform definition for safety management cannot be found, but quite many authors have the same opinion about elements which lead to good safety management (Hämäläinen and Anttila 2009). Levä (2003 p. 35-36) found in her wide literature review factors which seem to belong as a part of good safety management: the factors related to leadership and management, line organization, monitoring, measurement and auditing, as well as workers' commitment (Levä 2003 p. 35-36). Parallel results were found in qualitative interview studies performed twice: in 2000 and 2007. Below are factors that have been part of successful occupational health and safety management (Hämäläinen and Anttila 2009):

1. Safety policy
    a. includes concrete and visible objectives
    b. the commitment of top management is visible
    c. the status of employees is visible
2. Organizing
    a. systematic methods for safety and health activities
    b. defined requirements and responsibilities
    c. assured line organization resources
3. Methods
    a. risk assessment
    b. competence and skills
    c. measurements and monitoring
    d. interaction

Monitoring has become the focal requirement for the quality of safety in enterprises. The results of risk assessment or achievement of actions which are based on risk assessment, as well as competence and skills and interaction, can all be seen as a part of monitoring and measuring. After the Piper Alpha disaster Lord Cullen in his report insisted that "the performance standards which are to be met and the means by which adherence to these standards is to be monitored." (in Visser 1998 p. 43). Measurement and monitoring have become a key element for good safety management (Hämäläinen and Anttila 2009). A good safety record and success in business go hand-in-hand (Visser 1998 p. 43).

2.3.1 Safety measuring and monitoring

Safety is typically defined as the absence of danger, and thereby harm and loss, which gives evidence of performance improvement. Safety measurement and monitoring refers to that information and those procedures which are the basis of reaching the objectives, safety level and changes which have taken place (BS 8800:2004 p. 10). Success can be measured and monitored through the absence of failures (van Steen 1997 p. 3). Monitoring only harm or loss is inadequate, because they are issues which the management system is trying to prevent. Measurement and monitoring should emphasize positive indicators which measure the success of safety management without negative output. (ANSI/AIHA Z10-2005 p. 19; BS 8800:2004 p. 10; van Steen 1997 p. 3)

On the other hand, Hopkins (2009) questions the superiority of positive indicators in relation to negative ones. He gives two dimensions for safety indicators: personal safety versus process safety indicators, and lead versus lag indicators. Personal safety hazards affect individuals, while process safety indicators arise from the processing activity. Occupational accident and disease statistics reflect how well an organization is managing personal safety hazards. Lag indicator refers to, e.g. injury and fatality rates, while lead indicator refers to those indicators which directly measure the aspects of the safety management systems. (Hopkins 2009)

At the national level reactive indicators give the best information about the safety situation nationwide. Occupational accidents, work-related diseases, losses, etc. have to be measured, and they are the basis of safety performance at both company (ANSI/AIHA Z10-2005 p. 19; van Steen 1997 p. 3) and national level (ILO-OSH 2001 p. 3). Regulators can treat occupational accident and disease statistics as an indicator of how well safety is being managed in, e.g. a certain industry or occupation. They can encourage safety initiatives which affect this industry or occupation. A basis for national measurement and monitoring is a reliable and comprehensive compilation of statistics.

2.3.1.1 Compilation of occupational accident statistics

The figures of occupational accidents are published annually in many countries, but reliable data is available only in a limited number of countries, and the information is not standardized. However, statistical data is essential for accident prevention. (Jacinto and Aspinwall 2004; Purswell and Rumar 1984; Räsänen 2007 p. 142) With the help of occupational accident data it is known how, when and where occupational accidents occur. Occupational accident data is also essential at a global, national and enterprise level. Prevention of occupational accidents is probably the most common target in enterprises when they start their prevention program. As Macaskill and Driscoll (1998 p. 6) indicate “Occupational accident data provide a basis for comparing OHS performance across jurisdiction and industries at a point in time and monitoring trends and changing differentials

between groups over time. Accurate and reliable data are required to set goals for injury prevention and monitor progress towards achieving those goals."

Reporting of occupational accidents to the authorities varies between countries. Many European countries, as well as Australia, Japan, Canada, New Zealand and the USA, have different methods and collection procedures for occupational accidents. Member countries of the European Union have mainly two kinds of system to record their occupational accidents: (1) an insurance-based system, public or private, or (2) reporting is based on the legal obligation of the employer to notify accidents (Causes and... 2009 p. 116). The reporting level is typically quite high - around 100 per cent - in the former system, while the reporting level is only 30 to 50 per cent in the latter system (Causes and... 2009 p. 116). For example, the reporting system of occupational accidents in Finland is based on the private insurance system. Every employer has to have statutory workers' compensation insurance. If an occupational accident occurs in the workplace, the worker has right to receive compensation. The employer has an obligation to make an accident report to the insurance company. Private insurance companies give their information about accidents at work to the Federation of Accident Insurance Institution, which collects all information on the occupational accidents of employees and it publishes statistics on occupational accidents and diseases. Statistic Finland keeps records of occupational accidents. Their statistics also cover the occupational accidents of self-employed workers and agricultural workers as well as government workers. In Finland the reporting level is very high: almost 100 per cent.

According to Kjellén (2000 p.16), the differences in the reporting requirements mainly concern the classes of workers to be included in the reporting and the severity thresholds for reporting. Kjellén presents two usually used levels of reporting (Kjellén 2000 p. 16):

- Immediate reporting of severe accidents to the authorities.
- The requirement to report less severe accidents. The reporting requirements depend on the national laws.

In the case of a fatal or serious occupational accident occurring in Finland, the employer has to report the accident immediately to the occupational safety and health inspectorate, police and insurance company. A serious accident is an event which causes a high probability of a permanent handicap and complicates the injured worker's normal life.

At the enterprise level accident information can be divided into internal and external reporting (Lind and Kivistö-Rahnasto 2008). Internal reporting is based on the company's own internal situation (Baram 1997 p. 167), while external reporting gives information from other organisations to the company (Lind and Kivistö-Rahnasto 2008). Information on internal accidents is needed to prevent future re-occurrence (Baram 1997 p. 174), but also provides information for measuring the adequacy of safety management.

The importance of internal reporting has been studied in several research projects. It was found that companies with low accident rates have a better injury record-keeping system (Cohen 1977; Simonds and Shafai-Sahrai 1977) and frequent use of accident investigations and formalized accident reporting systems (Smith et al. 1978). An internal reporting system in companies is essential for a reliable national recording system, but it is also essential for the company's own purposes (Boyle 2003 p. 268). Companies will lose a good source of data to use for preventive purposes if they do not have an internal recording system (Jacinto and Aspinwall 2004; Smith et al. 1978).

In many cases the reliability of occupational accident data at a national and global level is inadequate. The information which is collected and the methodology which is used varies (Jacinto and Aspinwall 2004; Macaskill and Driscoll 1998 p. 5). Macaskill and Driscoll (1998 p. 5) indicate in their study the limitations of data available for occupational accidents, including the lack of coverage of self-employed workers, lack of data on less severe accidents, missing data, non-compliance with data standards, restricted number of variables and limitations imposed by the coding used for those variables. However, while developed countries mainly have national registration systems, the figures for accidents in developing countries are not based on proper accident recording and notification systems. Many developing countries record only accidents that have taken place in the case of businesses covered by accident insurance (Jacinto and Aspinwall 2004).

Global figures for occupational accidents are missing in spite of the fact that ILO keeps records of occupational accidents (fatal and non-fatal) and all member countries should give ILO information on accidents which have occurred. The accidents reported to ILO comprise only 3.9% of the estimated number of accidents that have occurred in the world. There is recording difference between fatal and non-fatal occupational accidents. At least in developed countries fatal accidents are virtually all recorded, but part of non-fatal accidents might be missing (European statistics... 2001 p. 27; Macaskill and Driscoll 1998 p. 7). For example, Leigh et al. (2004) have shown that between 33% to 69% of all occupational injuries were missing from the injuries reported in the USA.

Some regions such as the European Union have successfully combined accident figures of member states of the EU. Member countries of the EU use occupational accident data for the development of preventive policies, the planning of inspection activities and for financial purposes. Nevertheless, Jacinto and Aspinwall (2004) in their study found two major problems for the production of statistics at a European Union wide level: coverage of the labour force and different classification and coding schemes. In addition, the number of occupational accidents in those countries where reporting is based on the legal obligations of employers are estimations (Causes and... 2009 p. 116).

2.3.1.2 Compilation of work-related disease statistics

In the same way as in the case of recording occupational accidents, the recording of occupational diseases is lacking (Eurogip-01/E 2002 p. 11; Spreeuwers 2008 p. 9). As the ILO convention C155 (1981) states, all countries should maintain a registration system that is capable of providing information for policy makers. ILO has 182 member countries and only 53 have ratified it. Most developed countries have registries for occupational diseases though the definition of occupational diseases varies in different countries. The traditional occupational disease registration is insufficient, covering, typically, the classical occupational diseases. However, the recent trend is to include work-related diseases in countries' national lists of occupational diseases. (Spreeuwers 2008 p. 9)

Spreeuwers (2008 p. 163) indicates that a major insufficiency of registries of occupational diseases is their incompleteness of coverage. Eurogip research into the under-reporting of occupational diseases in Europe lists common reasons for the missing information. The insurance system not recognising possible exposure causing occupational diseases, the lack of knowledge and training of general practitioners, workers' fear of losing their jobs and the inadequate number of industrial doctors were seen as the main reasons for under-reporting. (Eurogip-03/E 2002 p. 12) Spreeuwers (2008 p. 163) made almost the same conclusion in his research in listing several causes of underreporting and levels of causation:

1. workers do not consult to physician,
2. occupational diseases are not recognized and diagnosed by a physician,
3. occupational diseases are recognized but not reported to the registry, and
4. occupational diseases are reported but not registered due to the limitations of the adjusted case definition. (Spreeuwers (2008 p. 163)

The number of occupational diseases depends on the current legislation in force in each country (Eurogip-01/E 2002 p. 11). Data on work-related diseases is needed for prevention purposes. The prevention of work-related diseases takes place on a national and company level, and the information needed is different (Verma et al. 2002). In addition, prevention activities take place also on a global level, mainly advocated by ILO and WHO. According to Spreeuwers (2008 p. 157), the information needed varies between these different prevention levels

1. the time-trends of occupational diseases are needed for setting policy priorities,
2. cases of new occupational diseases for early preventive action,
3. the disease patterns in specific occupational groups for focused prevention measures,
4. an overview of the consequences of occupational diseases and resulting measures for policy evaluation purposes, and
5. a description of blind spots that reveal in which areas further investigation is needed.

Global statistics on occupational diseases, not to mention work-related diseases, are totally missing. However, the Harvard School of Public Health published first estimates of the global burden of disease at the regional level (Murray and Lopez (ed.) 1996). The data covers not only occupational diseases, but all diseases. Newer global estimates have been published by WHO, covering all diseases.

Spreeuwers (2008 p. 159) stresses that different methods and instruments should be used in the prevention of work-related diseases. If only registration activities are used, then especially new work-related diseases might remain unknown.

3 THEORETICAL FRAMEWORK AND OBJECTIVES OF THE STUDY

Comprehensive statistics on occupational accidents and work-related diseases are, in part, based on the reliable collection of incidents. National records are based on data gathered from organizations. Thus, the responsibility of society is to develop a system which supports the monitoring of incidents in organizations and encourages organizations to record all the incidents that have occurred. Safety authorities and regulators base national safety and health policy on information that is available. In the case of insufficient information, the given recommendations and given resources might be directed towards a less effective safety and health performance. In addition, national safety and health policy may also produce inaccurate and incorrect objectives.

Most countries have a legal obligation to report occupational accidents and diseases. Incidents are reported to national social security offices or to insurance companies. (Kjellén 2000 p. 146) With the help of the statistical data the authorities consider areas of focus, e.g. economic branches, occupation, gender and/or age. The authorities are also responsible for the development of regulations and need reliable statistical data, which national reporting system produces (Kjellén 2000 p. 17).

The available statistics are influenced by the concept of occupational accidents and work-related diseases. In order for occupational accidents or work-related diseases to be recorded, an accident has to occur or a worker has to be exposed to a harmful condition in the workplace, which in turn leads to work-related disease. This does not still ensure that the occupational accident or work-related disease ends up on official records. Depending on an individual country's e.g. coding system, criteria of acceptance and current recording procedures, an incident is reported or not reported in the official system. Former and present accident theories have affected understanding of the causes of occupational accidents and are hence related to the definition of occupational accidents. Work-related diseases might be recorded in an organization´s own registration, but only occupational diseases might end up in the official record.

This doctoral thesis focuses on preventing occupational accidents and work-related diseases in the future. The present study cannot directly affect the available statistics. Existing statistics, even based on estimates, guide countries in their national policy and decision-making. Estimates are needed to motivate better occupational safety work, especially in countries where official recording systems are missing or lacking. Limited resources together with, e.g. industrialisation, urbanisation and social conditions make demands on occupational

safety and health. Estimates increase the awareness of work-related diseases, which seem to be an increasing problem in the whole world. The global estimates produced might affect national safety and health policy, which in turn make improvements in terms of the available statistics. Because global figures of occupational accidents and work-related diseases have been missing, a model to estimate global figures is needed.

In the present study, the central themes for the usefulness and functioning of occupational accident and work-related disease statistics are:

- definition of occupational accidents and work-related diseases
- occupational accident theories which affect the concept of causes
- causes of work-related diseases
- justification for compilation of statistics

The theoretical starting point is to understand what are occupational accidents and work-related diseases as well as what factors affect their origin. One important aspect is also to understand the importance of compiling statistics and the difficulty of making comparisons at the country level. First of all it is important to understand the significance of compiling statistics in terms of preventing further occupational accidents and work-related diseases. The theoretical framework in the present study is based on these considerations. Figure 3.1 presents the theoretical framework including the study process.

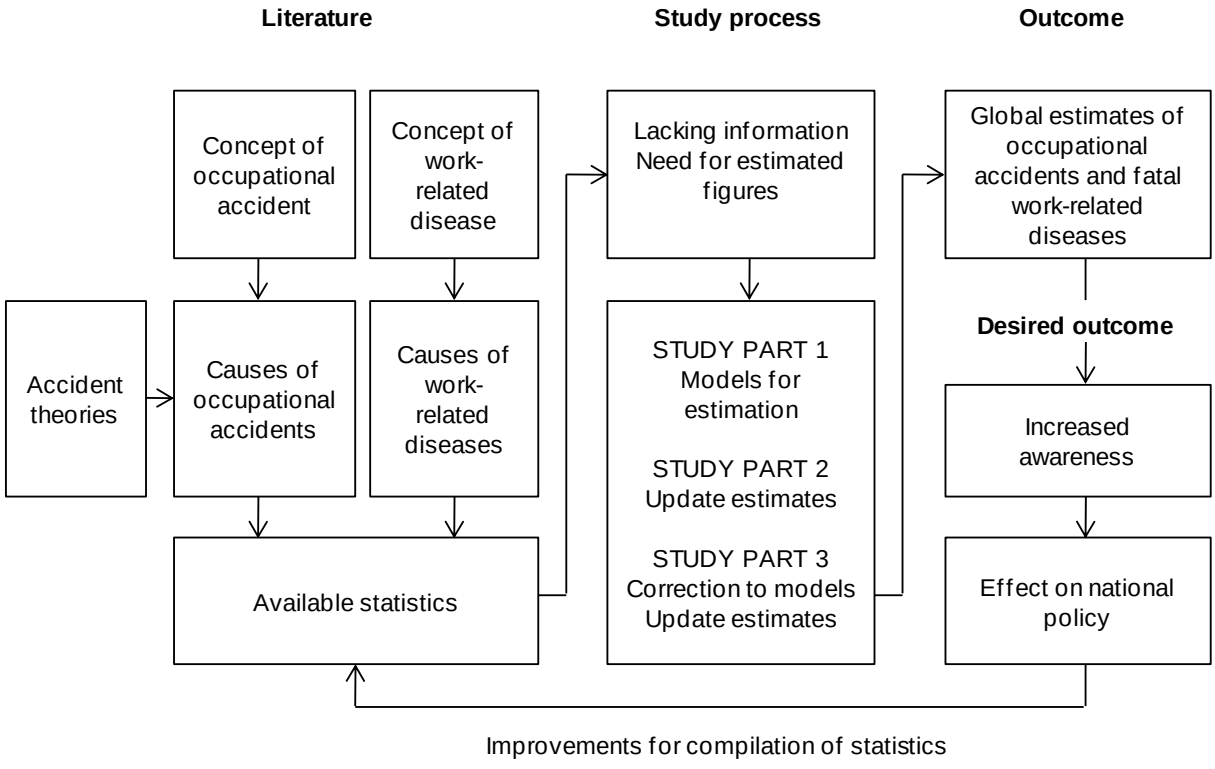


Figure 3.1 Theoretical framework of the present study

The ultimate purpose of the study was to increase an awareness of safety and health issues worldwide. It is hoped that the results will affect national policy and guide national policy makers towards better safety and health work. National safety and health management in turn directs safety and health work in companies. The objectives of the study were to create models to estimate the number of occupational accidents and fatal work-related diseases. The study was carried out in three parts: the initial study and two update studies.

Study part 1: Global estimates of occupational accidents and fatal work-related diseases

In the first study, which covers the year 1998 in the case of occupational accidents and the year 2000 in the case of fatal work-related diseases, the models for global estimation of occupational accidents and fatal work-related diseases were developed. The first study part was carried out during 2001-2002 and the sub-objectives were:

1. to estimate globally the number of occupational accidents that caused death or at least four days' absence from work.
2. to estimate globally the number of fatal work-related diseases by region, gender and age.

Study part 2: Second study of global estimates of occupational accidents and fatal work-related diseases

The objectives of the second study part were:

1. to update the global estimates of occupational accidents covering the year 2001.
2. to estimate fatal work-related diseases at the country level.

Fatal work-related diseases were estimated in the first study part by region and not by country level. The update study part was carried out in 2003-2004. The same models were used as in the first study.

Study part 3: Third study of global estimates of occupational accidents and fatal work-related diseases

The third study part was carried out in 2005-2006 and the objectives were:

1. to correct the estimation models.
2. to update estimates of occupational accidents and fatal work-related diseases by region and country level.
3. to update estimated number of fatal work-related diseases by disease groups, age and gender.

The updated number of occupational accidents is based on employment and accident figures from the year 2003 and the updated figures for work-related diseases are based on disease figures from the year 2002. The model was corrected only slightly in order to obtain comparable results.

The study also has further objectives, which emerged during the course of the study. Two of them were taken into account:

1. the effect of globalisation
2. the effect of competitiveness on occupational safety.

Globalization has many positive and negative impacts, depending on the country and region (Facci 2002; Palmowski 2003), and the effects were considered from the perspective of the number of occupational accidents. The earlier study of ILO showed that competitive countries are also the safest. In the ILO study only the industrialised countries were taken into account. In the present study all countries which have a competitiveness index were included.

4. MATERIALS AND METHODS

The study was carried out in three separate parts: the initial study and two update studies. The study consists of two sections: global estimates of occupational accidents and global estimates of fatal work-related diseases. The study of global estimates of occupational accidents was divided further into two sub-sections: estimation of fatal accidents and estimation of accidents causing at least 4 days' absence from work (Figure 4.1).

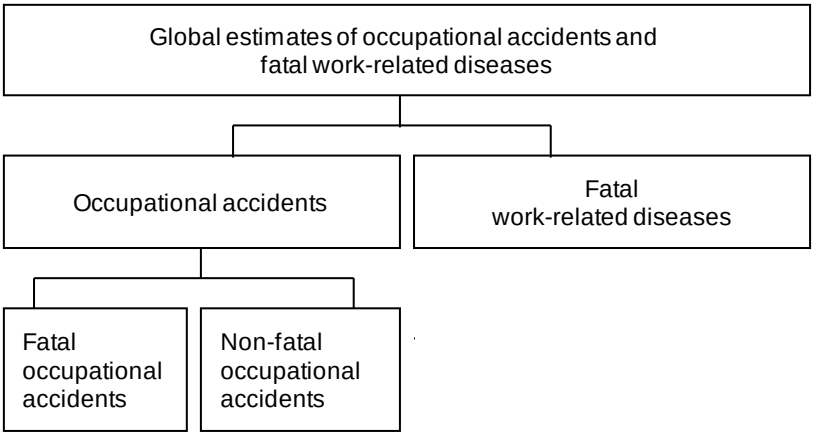


Figure 4.1. Sections of the study

The estimates of occupational accidents and fatal work-related diseases were given by region. The World Bank regional divisions were used in the two first study parts to estimate occupational accidents and work-related diseases. In the third part, the World Health Organization (WHO) regional divisions were chosen instead of those of the World Bank. The reason for this was that the World Bank changed its regional divisions at the time between the second and the third parts of the study. The WHO regional divisions are more accurate and the figures for the global burden of diseases were found from the WHO regional divisions. The World Bank used 8 regions and the WHO uses 6 main regions (Table 4.1).

Table 4.1. World Bank and World Health Organization regional divisions.

The World Bank regional divisions	The World Health Organization regional divisions
Established Market Economies (EME)	Africa (AFRO)
Formerly Socialist Economies (FSE)	Americas (AMRO)
India (IND)	South-East Asia (SEARO)
China (CHN)	Europe (EURO)
Other Asia and Islands (OAI)	Eastern Mediterranean (EMRO)
Sub-Saharan Africa (SSA)	Western Pacific (WPRO)
Latin America and the Caribbean (LAC)	
Middle Eastern Crescent (MEC)	

The WHO regions are divided further into 14 sub-regions. The sub-regions were used in the third part of the study in order to obtain the best possible estimates. In the two first studies, China and India formed their own region. In the WHO divisions, China belongs to the WPRO and India to the SEARO region.

4.1 Global estimates of occupational accidents

The global estimates of occupational accidents are calculated for the years 1998, 2001 and 2003. The newest information found in the study period was used to calculate occupational accidents. The model for estimating the global number of occupational accidents, both fatal and occupational accidents causing at least 4 days' absence, was the main result in the first part of the study, while in the other parts of the study updated figures were calculated using the same model. The results of all parts of the study were given at regional and country level (Paper I, III and IV). Figure 4.2 presents the progress of the study regarding estimates of occupational accidents.

4.1.1 Fatal occupational accidents

The basis for the calculations was the economically active population and total employment information (covering both paid employment and self-employment), which was collected mainly from ILO Laborsta and the website Population Statistics. The labour structure was divided into three sectors: agriculture, industry and service. Information on the labour structure was given as a percentage and was gathered from ILO Laborsta and the Central Intelligence Agency (CIA).

Information from the World Fact Book and Population Statistics was used for the calculations. For these three sectors fatality rates were formed by region. The total employment figures were used if found. Otherwise, the number of persons forming the economically active population was used. Estimates of occupational accidents were made by region, so that in each region some countries were chosen to represent the whole region. The information which was needed from each individual country was a) the number of fatal

occupational accidents by insured/covered employees, and b) the fatality rate per 100,000 insured/covered employees. However, only a few countries in each region had reliable information available. To make the calculations for regions, the countries that best represented the region were chosen. The phases of the calculations are presented in more detail below (see also Figure 4.2).

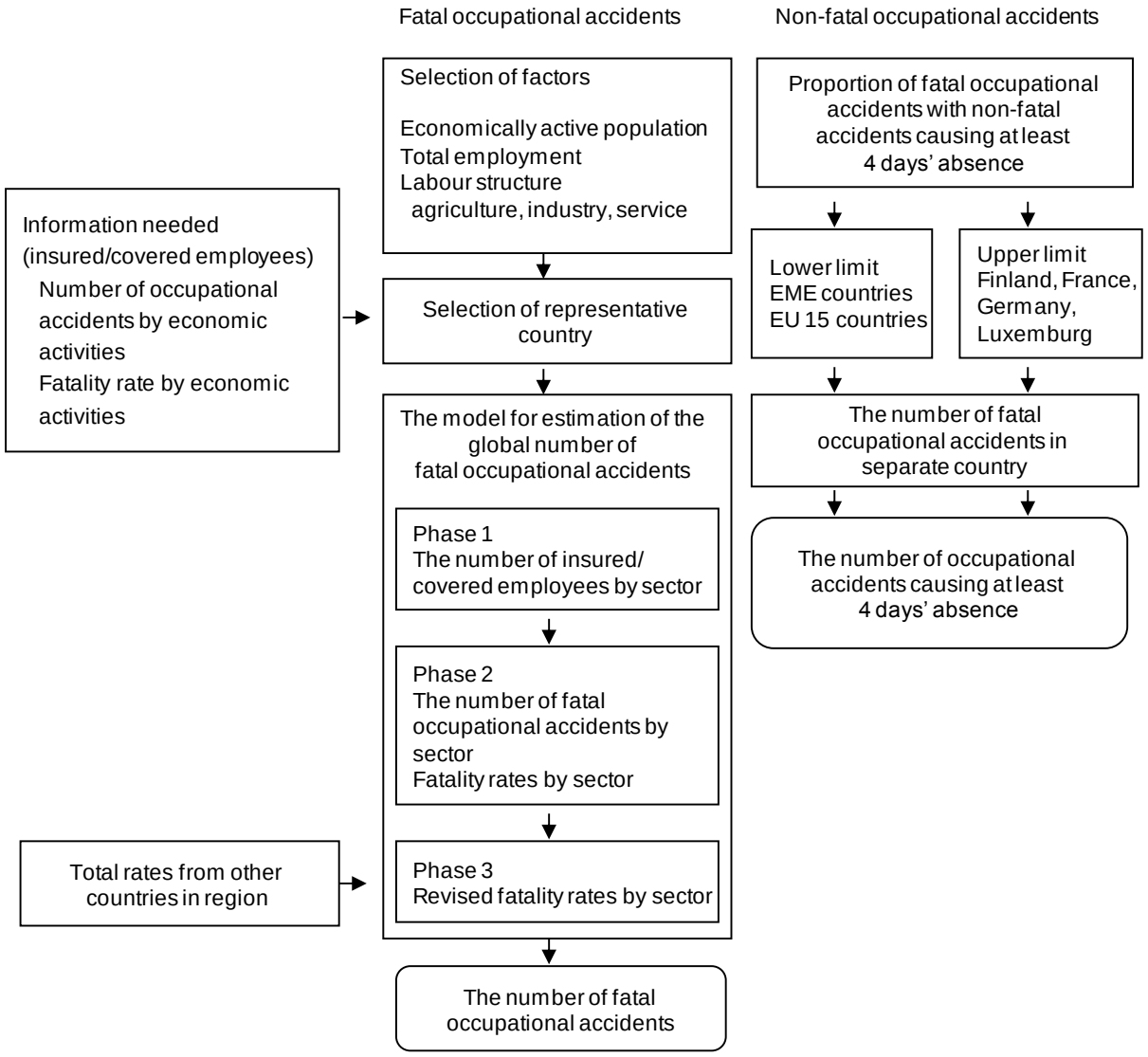


Figure 4.2. Progress of the study for global estimation of occupational accidents

Phase 1: The number of insured/covered employees by sector was calculated for the selected countries. Accident rates per 100,000 insured/covered employees and the number of fatal accidents for insured/covered people at the country level were taken from Laborsta ILO.

Phase 2: The number of fatal occupational accidents and fatality rate per 100,000 for fully employed persons by sector were calculated when the total employment figure was known

(data collection mentioned above). In case the figure was missing, the figure of economically active population was used.

Phase 3: The rates were revised. From each region at least one country, which can be assumed to have data reliably reported by sector, was obtained. However, in each region several countries that have reliable total accident rates were discovered. The mean value of the rates which were used was as up to date as possible and usually covered the three last years: in the first study the years 1997-1999; in the second study 1999-2001; and in third study 2001-2003. By using proportionality the final revised rates were calculated.

Finally, by using the rates obtained from the calculations the number of fatal accidents by sector (agriculture, industry and service) could be calculated for each country. The total number of fatal occupational accidents was obtained by summarizing the fatal accidents in each sector. More detailed examples of calculations based on the area of Formerly Socialist Economies (FSE) are presented in Paper I. Tables 4.2 and 4.3 present the rates and countries of each region used for the calculations. The first country mentioned on the list is used to form the sectoral rates and the others are used for making revisions (Table 4.2 and 4.3).

Table 4.2. Fatal accident rates per 100,000 employees by region and labour sector in 1998 and 2001

Region	Year	Calculated rates by labour sector			Countries used on calculation
		Agriculture	Industry	Service	
FSE	1998	8.4	21.9	5.7	Kazakhstan, Russia
	2001	10.5	20.3	5.8	Kazakhstan, Russia
India	1998	10.2	26.4	6.9	Kazakhstan, Malaysia
	2001	9.5	18.3	5.2	Kazakhstan, Malaysia
China	1998	8.1	21.0	5.5	Kazakhstan, China
	2001	11.4	22.1	6.3	Kazakhstan, China
OAI	1998	34.9	13.4	7.9	Korea, Rep. of Malaysia, Thailand
	2001	31.1	12.0	7.0	Korea, Rep. of Malaysia, Thailand
SSA	1998	22.5	16.0	18.7	Zimbabwe, Ethiopia
	2001	19.5	13.8	17.4	Zimbabwe, Ethiopia, Togo
LAC	1998	33.3	13.4	10.8	Argentina, Brazil, El Salvador, Nicaragua, Panama
	2001	27.9	21.3	15.5	Argentina, Brazil, El Salvador, Nicaragua
MEC	1998	21.2	21.2	12.4	Turkey, Egypt, Morocco and Tunisia
	2001	26.3	19.0	10.1	Turkey, Tunisia

FSE=Formerly Socialist Economies, OAI=Other Asia and Islands, SSA=Sub-Saharan Africa, LAC=Latin America and Caribbean, MEC=Middle Eastern Crescent

In the case of Sub-Saharan Africa, the total employment figures were not available in most countries. The accident figures are therefore based on the figures for the economically active population.

Table 4.3. Fatal accident rates per 100,000 employees by region in 2003

Region	Calculated rates by labour sector			Countries used on calculation
	Agriculture	Industry	Service	
AFRO D	25.8	18.2	21.3	Zimbabwe, Algeria, Togo, Ghana
AFRO E	20.1	14.3	16.6	Zimbabwe, Mozambique, Namibia and South Africa
AMRO B and D	25.5	19.4	11.7	Argentina, Chile, Costa Rica, El Salvador
EMRO B and D	24.6	15.4	4.7	Tunisia, Bahrain, Turkey
India	9.5	18.3	4.8	Kazakhstan, Malaysia
EURO B	10.0	19.2	5.0	Kazakhstan, Romania, Slovakia, Turkey
EURO C	8.8	16.9	4.4	Kazakhstan, Estonia, Lithuania, Russia, Ukraine
SEARO B and D	33.6	12.9	7.6	Korea, Malaysia, China
WPRO B	33.6	12.9	7.6	Korea, Malaysia, China
China	12.4	23.9	6.2	Kazakhstan, China

AFRO=Africa, AMRO=Americas, SEARO=South-East Asia, EURO=Europe, EMRO=Eastern Mediterranean, WPRO=Western Pacific

Developed countries are also exceptions. For these countries information on the number of fatal occupational accident was found, but it was revised. In two first parts of the study, the accident figures of Established Market Economies (EME) were based on the figures reported to ILO or on the statistics centres of these countries. The EU has its own statistics office, Eurostat. Its information was used for the EU 15 countries[1] (Dupré, 2001). Still, all figures were adjusted, because both sources of occupational accident statistics cover only wage earners. The figures for fatal accidents were corrected using the ratio: total employment reported to ILO per total employment reported to the EU (153,364,323 / 136,500,000=1.126). The total employment reported to ILO also covers self-employed persons and self-employed agricultural workers. The calculated ratio was used for all EME countries.

In third part, the ratio was formed differently. For the EU 15 countries, the number of fatal occupational accidents was taken from the Eurostat webpage. Currently, Eurostat figures also cover self-employed persons and farmers. When the Eurostat number of occupational accidents for the EU 15 countries is compared with the ILO number of occupational accidents, it is seen that approximately 81.3% of all fatal accidents are covered in ILO statistics. The figures for the selected EU countries, i.e. Austria, Finland, France, Italy, Spain and the United Kingdom, were used to form the ratio. These countries were chosen because the number of occupational accidents in 2003 for all of them could be found in both sources of statistics: ILO and Eurostat. The figures for other EU countries were corrected using this ratio (100%/81.3%=1.23). This proportion was mainly used for the same countries that

[1] The EU 15 countries are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.

belong to the EME region, which are EURO A countries and other EU countries, most of AMRO A and WPRO A countries.

4.1.2 Non-fatal accidents

Accidents causing at least 4 days' absence from work were calculated using lower and upper limit estimates. In the first two parts of the study the lower limit was calculated by using the proportions of fatalities for each EME country and in the third part for EU 15 countries except Portugal with accidents causing at least 4 days' absence and obtaining the average of these proportions.

In the EU the declaration rate is estimated to be 100% in only some countries (Dupré 2001). The upper limit was formulated by using the proportion of fatal accidents in Finland, France, Germany and Luxemburg with the figures for accidents causing at least 4 days' absence. Accidents causing at least 4 days' absence for each country in all regions were then calculated by using lower and upper limits. The average is arrived at by calculating the mean value of the lower and upper limits.

At least 4 days' absence means here the same as more than three days' absence from work. The term at least 3 days' absence is used in Paper I and Paper III, but actually calculates the number of occupational accidents causing more than three days' absence excluding the day when the accident happened. (European statistics... 2001 p. 12)

4.2 Global estimates of fatal work-related diseases

The first two parts of the study on global estimates of fatal work-related diseases used mainly two sources of information: The Global Burden of Disease (GBD) (Murray & Lopez (Ed.), 1996) and the Epidemiologic Estimate of the Proportion of Fatalities Related to Occupational Fraction in Finland (Nurminen & Karjalainen, 2001). In the third part of the study, GBD statistics have been replaced by the WHO global burden of disease (GBD) estimates (WHO 2002). The attributable fractions from Nurminen and Karjalainen (2001) were still used in the third part in order to make the estimates comparable.

Global estimates of fatal work-related diseases are estimates for the years 2000 and 2002. Data on the global burden of disease could only be found for those years. The first results gave a model to estimate fatal work-related diseases at the regional level (Paper II) and in the second study the results were given by country level. In the third part of the study new estimates were calculated both at regional (Paper V) and country (Paper IV) level. Estimates were made according to regions and by groups of diseases. The regions used are the same as were mentioned earlier: The World Bank regional divisions were used in the first two parts

of the study and in the third part the WHO regional divisions were used. Figure 4.3 presents the progress of the study concerning estimates of fatal work-related diseases.

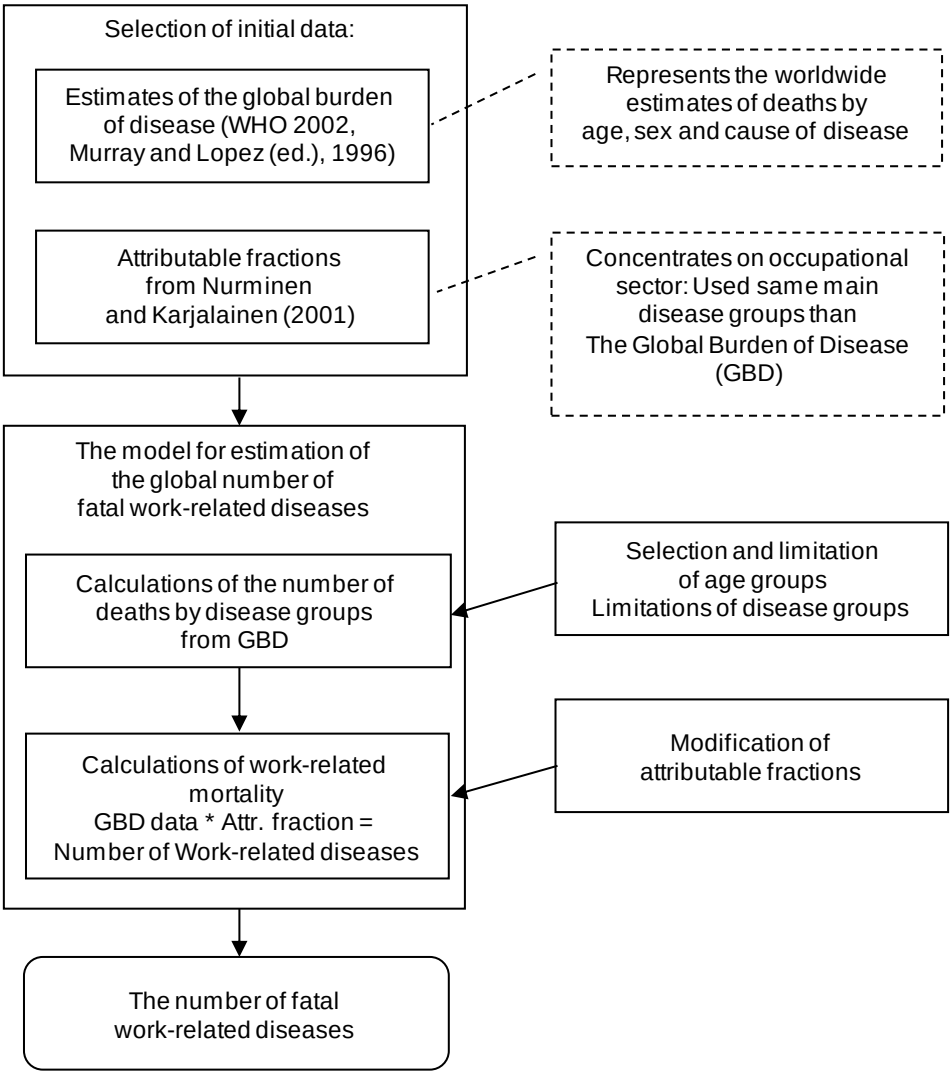


Figure 4.3. Progress of the study for global estimation of fatal work-related diseases

Both GBD estimates (the WHO and Murray and Lopez (Ed.) 1996) provide worldwide estimates of deaths categorized by age, sex and causes of disease, and was found to be the only source which covers the entire world. GBD figures include not only occupational diseases, but all diseases and deaths (Murray and Lopez (Ed.), 1996; WHO 2002). Diseases are further divided into more specific disease groups. For this doctoral study, only the seven main disease categories were used: communicable diseases, malignant neoplasms, respiratory diseases, circulatory diseases, neuropsychiatric conditions, digestive diseases, and genitourinary system diseases.

The attributable fractions for the study were mainly taken from Nurminen and Karjalainen, as these were formed for the same disease categories as for GBD. The attributable fractions

are based on a wide literature review (although mainly from industrial countries), and the fractions were the newest ones that could be found. The attributable fractions given are based on exposure estimates, the known exposure-disease relationship of different work-related diseases, and from figures registered by Statistics Finland. (Nurminen and Karjalainen, 2001)

Since not all the diseases from GBD can be considered work-related, some categories of diseases were disregarded for this study, including childhood-cluster diseases, maternal and perinatal conditions, and nutritional deficiencies. The disease groups not included in Nurminen and Karjalainen (2001) were also excluded (rheumatic heart disease, inflammatory heart disease and other cardiovascular diseases). In this study, circulatory system diseases included only ischaemic heart and cerebrovascular diseases.

In both GBD, the age groups were divided into seven different categories: 0-4, 5-14, 15-29, 30-44, 45-59, 60-69, and 70+. In this study, all age groups, except the group from 0-14 years, were used. Also, the group 70+ was used because the latency time of quite many diseases is long. Any error caused by disregarding the 0-14 years group was assumed to be quite small as both of the extreme age groups at least partially compensate for each other. It is well known that in some countries children under 15 years are working in very poor and hard conditions and are exposed to substances leading to diseases. On the other hand, people in their 70s are retired, but are still exposed to or affected by different substances having either long-lasting effects or a long latency time.

Limitations were made for all age groups depending on the disease group, as Nurminen and Karjalainen (2001) had divided the age groups differently. Their study excluded all deaths for people under 25 and over 74 years old. Their study also excluded groups over 65 years for two disease groups - communicable and digestive system diseases - but included persons over 65 in the other disease groups because of the long latency period of these diseases. For circulatory system diseases, the study included only 25% of cases in the oldest age group. These exclusions and selections have affected the calculation of age groups from both GBD.

Some exclusions and selections were made for the disease groups. For communicable diseases in age groups 15-29, 30-44 and 45-59 all deaths were taken into account. For age group 60-69, only half of the deaths (50%) were counted. For the over 70 years group, no deaths were calculated. For malignant neoplasms, respiratory diseases, neuropsychiatric conditions, genitourinary system and digestive diseases, one third of the death (33%) figures were taken into account for those aged 15-29 years. All figures were included for all of the other age groups except for digestive diseases, from which the over 70 years group was excluded. For circulatory diseases one third of the figures were taken into account for those aged 15-29. Age groups 30-44 and 45-59 were included. For age group 60-69 approximately

58% of deaths and for age group 70+ 10% of deaths were included. Table 4.4 presents the age groups that were included in certain disease groups.

Table 4.4. Percentage of deaths in each age group included in the study

	Age groups included (%)				
	15-29	**30-44**	**45-59**	**60-69**	**70+**
Communicable diseases	100	100	100	50	
Malignant neoplasms	33	100	100	100	100
Respiratory diseases	33	100	100	100	100
Circulatory diseases[a]	33	100	100	App. 58	10
Neuropsychiatric conditions	33	100	100	100	100
Digestive diseases	33	100	100	100	
Genitourinary system	33	100	100	100	100

[a] GBD age groups differ from the age groups used by Nurminen and Karjalainen (2001) and were formed differently (see Paper II).

Work-related mortality was calculated by using either attributable or revised attributable fractions, depending on the region (Table 4.5). The attributable fractions of Formerly Socialist Economies (FSE), India and Sub-Saharan Africa (SSA) were revised: communicable diseases received more emphasis and all non-communicable diseases had a lower emphasis. In the third part of the study also communicable diseases were given lower emphasis. The attributable fraction of communicable disease was taken from the study results of Nurminen and Karjalainen (2001). They are based on the Finnish situation, where work-related communicable diseases are quite unusual and often lead to death. In other words, the attributable fraction for communicable diseases is calculated for industrialized countries and it already emphasises too much communicable diseases in developing regions. Revised attributable fractions were used in the first two study parts for SSA, FSE and India. In the third part of the study revised fractions were used for AFRO D and D (former SSA) and EURO B and C (former FSE) regions.

In EME, China, OAI, LAC and MEC, the same attributable fractions have been used as by Nurminen and Karjalainen (2001) in their calculations for Finland. The results for Established Market Economies give a good estimate of mortality, as the attributable fractions are based on epidemiological research done in industrialized countries. For China, Other Asia and Islands, Latin America and the Caribbean, as well as the Middle Eastern Crescent, the estimated figures are likely to be higher, as these regions are undergoing enormous changes. Industrialization, urbanization and the construction of infrastructure have increased the number of employees who face new, dangerous and hazardous situations. Agriculture is increasingly mechanized and uses high amounts of agrochemicals.

The attributable fractions for neuropsychiatric conditions have also been revised because Murray and Lopez (ed.) (1996) have categorized this disease group differently than have Nurminen and Karjalainen (2001). They calculated separate attributable fractions for mental

disorders and nervous system diseases. The revised attributable fraction was calculated using the proportion of attributable fractions compared to the total number of deaths that occur in Finland.

In the first two parts of the study work-related mortality was calculated separately by age group and gender. These two total estimates differed from each other. In the third part only attributable fractions by gender were used, because the WHO global burden of disease estimates are given separately for men and women and both gender groups are divided by age.

To obtain estimates of fatal work-related diseases at the country level, the regional estimates were divided according to proportion of employment. The total employment figure was always used when possible; otherwise, the figure for the economically active population was used.

Table 4.5. Attributable fractions used in estimations of fatal work-related diseases by gender and regions

	Men						Women					
Causes	**EME, China, OAI, LAC, MEC 2000[a]**	**Amro, Searo, Euro A, Emro, Wpro 2002[a]**	**SSA 2000[b]**	**Afro 2002[b]**	**FSE, India 2000[b]**	**Euro B, C 2002[b]**	**EME, China, OAI, LAC, MEC 2000[a]**	**Amro, Searo, Euro A, Emro, Wpro 2002[a]**	**SSA 2000[b]**	**Afro[b] 2002[b]**	**FSE, India 2000[b]**	**Euro B, C 2002[b]**
Communicable diseases	4.8		7.54	3.05	5.28	4.36	32.5		51.07	20.68	35.75	29.55
Malignant neoplasms	13.8		8.78		12.55		2.2		1.40		2.00	
Respiratory diseases	6.8		4.33		6.18		1.1		0.70		1.00	
Circulatory diseases	14.4		9.16		13.09		6.7		4.26		6.09	
Neuropsychiatric conditions[c]	6.6		4.20		6.00		1.8		1.15		1.64	
Digestive diseases	2.3		1.46		2.09		1.5		0.95		1.36	
Genitourinary system	3.0		1.91		2.73		0.4		0.25		0.36	

[a] Attributable fraction from Nurminen and Karjalainen (2001)
[b] Revised attributable fraction
[c] Revised attributable fraction for neuropsychiatric conditions

4.3 Effect of globalisation and competitiveness

Globalisation is often seen as the process by which businesses or other organizations develop international influence or start operating on an international scale (Black 2002; Soanes and Stevenson 2005). This process usually consists of changes in markets, production, finance and communications (Haery and Noon 2001). In this context, a more interesting issue is the influence of globalization on occupational safety.Paper III discusses the effect of globalisation on occupational accidents based on literature review.

In Paper VI the effect of competitiveness on occupational safety is discussed. Simple statistical analyses are used to consider how gross domestic product (GDP) per capita can explain work-related mortality. The global competitiveness index (GCI) is used to explain the occupational fatality rate. GDP was taken from Statistics Finland (2005) and World Economic Forum (Lopez-Claros et al. 2006 p. 14) competitiveness indexes was used. Occupational accident fatality rate is based on the results from the third part of the study. The data are presented at the regional level using the World Health Organisation (WHO) division into regions.

The first analysis is a linear regression in which the dependent variable is work-related mortality per 100,000 workers (mortality rate), and it is explained with the independent variable GDP per capita. Work-related mortality includes fatal occupational accidents and work-related diseases. The second analysis is also a linear regression which is used to test the dependency of fatal occupational accidents per 100,000 workers (fatality rate) on the GCI. Both mortality rate and fatality rates are formed using the number of the labour force. This gives figures which are too low, but total employment is not available in many countries and it was decided to use the same figure for all regions. Finally, a one-way analysis of variance was made to see how the GCI can be explained on a regional basis.

GDP per capita is a single factor, but the GCI is a holistic overview of factors which are critical elements of productivity and competitiveness. The GCI grouped factors into nine pillars (at present 12 pillars). These parts include a total of 89 variables, of which GDP is one. (Lopez-Claros et al. 2006 p. 5)

4.4 Summary of study papers

The methods explained above are presented in more detail in the six study papers. All the papers are based on three separate study parts. Part 1 of the study produced two papers. Paper I presents results which concentrate on the model for estimating occupational accidents. Estimates of both fatal occupational accidents and accidents causing at least four days' absence are presented at the global, regional and country level. Paper II presents

results which concentrate on the model for estimating fatal work-related diseases. Estimates of fatal work-related diseases are presented at the global and regional level.

Part 2 of the study produced Paper III, which discusses the effects of globalization on occupational accidents. Though the objectives of the second study were to update the global estimates of occupational accidents covering the year 2001 and estimate fatal work-related diseases by country level, only updated estimates of occupational accidents were published in the paper. The results for fatal work-related diseases are published together with the results of the third study in Papers IV and V.

Part 3 of the study produced three papers. Paper IV presents results which concentrate on estimates of occupational accidents in 1998, 2001 and 2003, and fatal work-related diseases in 2000 and 2002 at regional and country level. A correction of the model is presented and a comparison of the three estimates is made. Paper V presents results which concentrate on estimates of fatal work-related diseases in 2000 and 2002. Estimates of fatal work-related diseases in this paper are presented by disease groups, not at the country level. Paper VI shows that countries can improve their competitiveness if they put effort also into occupational safety and health. The gross domestic product, the World Economic Forum competitiveness index and estimates (the number of mortality and fatal occupational accidents from the second updated study) were used to explain occupational safety at the level of different continents. Table 4.7 summarises the three parts of the study and the papers. The main objectives, methods results and conclusions are presented.

Table 4.7. Description of papers comprising doctoral thesis

	Study 1		**Study 2**	**Study 3**		
Study period	2001-2002		2003-2004	2005-2006		
	Paper I	**Paper II**	**Paper III**	**Paper IV**	**Paper V**	**Paper VI**
Title	Global estimates of occupational accidents	Global estimates of fatal work-related diseases	The effect of globalization on occupational accidents	Global trend according to estimated number of occupational accidents and fatal work-related diseases at region and country level	Fatal work-related diseases – global estimates	The effect of competitiveness on occupational safety
Publisher	Safety Science 44 (2006) 137-156	American Journal of Industrial Medicine 50 (2007) 28-41	Safety Science 47 (2009) 733-742	Journal of Safety Research 40 (2009) 125-139	International Journal of Occupational and Environmental Health (Evaluation of the latest round of changes is in process)	IEEE International Conference on Industrial Engineering and Engineering Management Dec 2-4 2007 Singapore
Authors	Hämäläinen P, Takala J, Saarela KL	Hämäläinen P, Takala J, Saarela KL	Hämäläinen P	Hämäläinen P, Saarela KL, Takala J	Hämäläinen P, Saarela KL, Takala J	Hämäläinen P
Objectives	Develop the model for global estimation of occupational accidents	Develop the model for global estimation of fatal work-related diseases	Discussglobalization and its effects on occupational accidents and vice versa	Update estimates of global occupational accidents	Update estimates of global fatal work-related diseases	Present and discuss from the statistical point of view how gross domestic product (GDP) per capita and the global competitiveness index (GCI) can explain work-related mortality.

Methods	Data collection from trusted sources and based on literature review Calculation	Selection of initial data: global disease statistics and attributable fractions Calculation	Literature review	Use of same methods as presented in Paper I	Use of same methods as presented in Paper II	Statistical analysis
Results	Global estimates of occupational accidents in 1998	Global estimates of fatal work-related diseases in 2000	Global estimates of occupational accidents in 2001 and their effects on globalization and vice versa.	Trends of occupational accidents and fatal work-related diseases. Also calculation of fatal work-related diseases at country level.	Global estimates of fatal work-related diseases for year 2002 by disease groups. Comparison with results of the year 2000.	GDP per capita cannot explain work-related mortality. The GCI can explain fatal occupational accidents per 100 000 workers.
Conclusions	More occupational accidents than estimated earlier.	Work-related diseases are a bigger problem than assumed earlier.	Although globalization has affected the number of occupational accidents, it is difficult to demonstrate this.	Fatal occupational accidents remain quite the same. Occupational accidents causing at least 4 days' absence have increased clearly. Occupational accidents are an increasing problem in developing regions.	No big changes in the number of fatal work-related diseases. Awareness of work-related diseases increasing.	Good occupational health and safety work have effect on competitiveness.

5. RESULTS

5.1 Results from the study part 1

The results from the first part of the study indicate that approximately 2.3 million workers die because of occupational accidents and work-related diseases. Traditionally, countries have calculated only their occupational accidents and occupational diseases as defined by a national compensation system that represents only a small proportion of all work-related mortality. Work-related mortality is shown in Figure 5.1. The three main groups are malignant neoplasms (28%), communicable diseases (28%) and circulatory system diseases (20%). The proportion of occupational accidents is 15% of all work-related deaths, and this varies in each region. It is lowest in EME (5%) and the highest in OAI (34%).

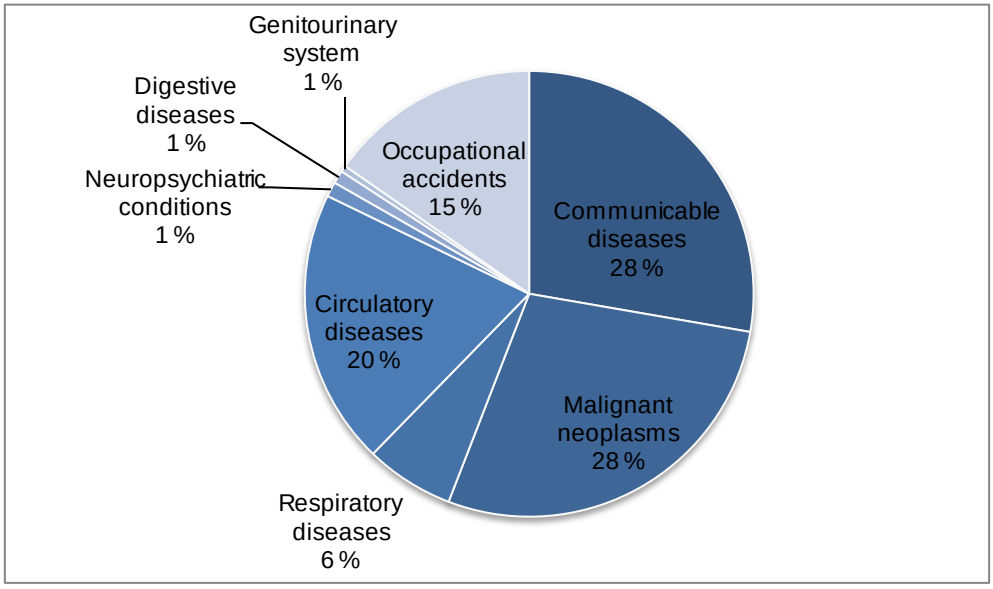


Figure 5.1. Global estimated work-related mortality by cause in 2000

In 1998 there occurred 345,000 fatal occupational accidents worldwide. Most of them occurred in the Asian continent in India (14%), China (24%) and other Asian countries (24%). On average 264 million occupational accidents which caused at least 4 days' absence from work occurred (Table 5.1). Every day some 950 people die and over 720,000 workers get hurt because of occupational accidents.

Table 5.1. The number of occupational accidents in 1998

		Occupational accidents causing at least 4 days' absence		
Region	**Fatalities**	**Lower limit**	**Upper limit**	**Average**
EME	16,170	8,510,494	16,169,938	12,340,216
FSE	21,425	11,276,461	21,425,275	16,350,868
IND	48,176	25,355,777	48,175,977	36,765,877
CHN	73,615	38,744,649	73,614,834	56,179,742
OAI	83,048	43,709,538	83,048,122	63,378,830
SSA	54,705	28,792,223	54,705,223	41,748,723
LAC	29,594	15,575,673	29,593,778	22,584,726
MEC	18,986	9,992,504	18,985,757	14,489,130
WORLD	345,719	181,957,318	345,718,904	263,838,111

Established Market Economies (EME), Formerly Socialist Economies (FSE), India (IND), China (CHN), Other Asia and Islands (OAI), Sub-Saharan Africa (SSA), Latin America and the Caribbean (LAC), Middle Eastern Crescent (MEC)

The fatality rate for EME region is 4.2 and accident rate 3,240 per 100,000 workers. The fatality rate for FSE region is 13 per 100,000 workers and the accident rate is 10,000 per 100,000 workers. Thus, every tenth worker has an occupational accident during one year (see Paper I).

Annually, over 48,000 workers die because of occupational accidents in India, and almost 37 million occupational accidents which cause at least 4 days' absence from work occur. The fatality rate is 11.4 per 100,000 workers and accident rate 8,700 per 100,000 workers. In China both rates are close to those in India. The fatality rate is 10.5 per 100,000 workers and the accident rate 8,028 per 100,000 workers. In the countries of other Asia and Islands the fatality rate per 100,000 workers is 21.5 and the accident rate per 100,000 workers is over 16,000 (see Paper I).

In Sub-Saharan African countries the fatality rate of the region is 21 per 100,000 workers and the accident rate per 100,000 workers is 16,000. The fatality and accident rates are almost the same in every country. As really reliable information was obtained from very few countries, most figures are based on proxy figures (see Paper I).

In the area of Latin America and the Caribbean the fatality rate per 100,000 workers is 24.9 and the accident rate per 100,000 workers is 18,000. In the region of the Middle Eastern Crescent the fatality rate is 20.0 per 100,000 workers and the accident rate per 100,000 workers is 15,000 (see Paper I).

Agriculture is still a very dangerous sector worldwide and especially in developing regions it is the most dangerous field (Table 5.2). Agricultural workers are typically self-employed persons and it might be that accidents happening to them do not even show in the figures.

Table 5.2. Proportion of fatal occupational accidents in 1998

	Proportion of fatal occupational accidents by sector (%)		
	Agriculture	**Industry**	**Service**
FSE	22.36	50.35	27.29
IND	57.74	28.74	13.52
CHN	38.49	47.91	13.60
OAI	79.34	9.69	10.97
SSA	71.49	7.34	21.17
LAC	46.92	18.70	34.38
MEC	37.87	29.91	32.22

The largest groups of work-related diseases worldwide are cancers, circulatory diseases and communicable diseases. Figure 5.2 shows work-related mortality according to region. It can be seen that in all regions except for Sub-Saharan Africa, the proportion of diseases follows the proportions for the world in general. In SSA and India, communicable diseases caused the most work-related deaths.

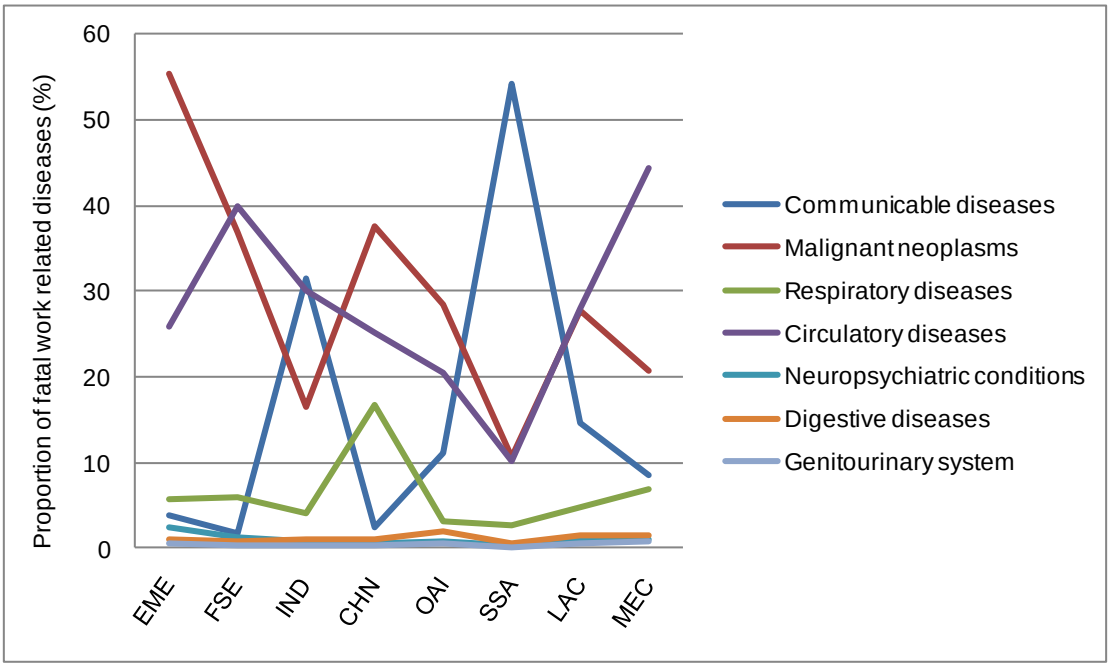


Figure 5.2. Fatal work-related mortality by region and cause in 2000

The proportion of malignant neoplasms and circulatory system diseases is significant in almost all regions, and it might still grow in the future because the proportion of communicable diseases is expected to diminish. The proportion of neuro-psychiatric conditions is very low in all regions, varying between almost 0% and 3%, even though it seems that the number of mental disorders is growing. The likely reason is that these disorders are causing high rates of disability, but not very high mortality (see Paper II).

When work-related diseases are considered by age, the latency period is emphasized. As is shown, communicable diseases have a short latency period (Figure 5.3). Most deaths occur in workers aged between 15 and 59, even though immunity is usually lower in older people. Malignant neoplasms and respiratory system diseases have a long latency period, so most of these deaths occur in older workers (for more detail information see Paper II).

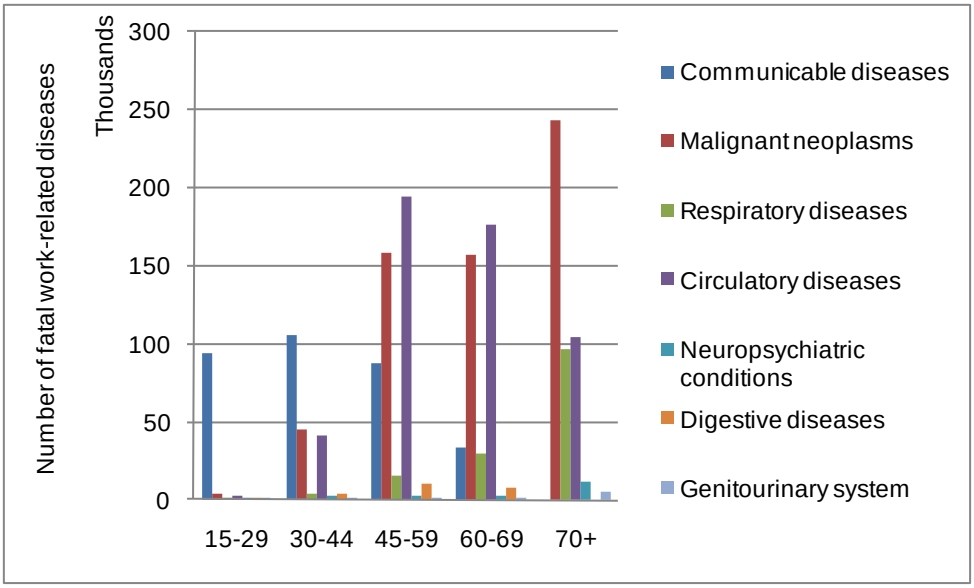


Figure 5.3. Fatal work-related diseases by age and cause in 2000

5.2 Results from the study part 2

In 2001 there occurred over 350,000 fatalities (Table 5.3). Thus, each day approximately 1,000 people die because of occupational accidents. It has been estimated that nearly 270 million occupational accidents causing at least 4 days' absence from work occurred during the year 2001.

Table 5.3.Number of occupational accidents in 2001 and fatal work-related diseases in 2000 at regional level

	Occupational accident causing at least 4 days' absence					
Region	**Fatalities**	**Lower limit**	**Upper limit**	**Average**	**Fatal work-related diseases**	**Deaths caused by dangerous substances**
EME	15,879	8,357,512	15,879,274	12,118,393	286,998	55,688
FSE	17,416	9,166,254	17,415,882	13,291,068	153,564	31,571
IND	40,133	21,122,666	40,133,065	30,627,865	325,350	67,089
CHN	90,295	47,523,941	90,295,489	68,909,715	414,024	92,960
OAI	76,886	40,466,285	76,885,941	58,676,113	208,402	52,619
SSA	53,292	28,048,284	53,291,739	40,670,012	387,721	81,120
LAC	39,372	20,722,028	39,37, 853	30,046,941	116,135	28,502
MEC	17,977	9,461,769	17,977,361	13,719,565	140,941	29,379
WORLD	351,251	184,868,738	351,250,604	268,059,671	2,033,135	438,928

The number of fatal work-related diseases is the same as estimated in the first part of the study. Estimations were continued to the country level and published in Paper IV. It was also estimated that the number of deaths caused by dangerous substances is approximately 440,000.

5.3 Results from the study part 3

The estimates from the third part of the study show that still approximately 2.3 million workers die because of occupational accidents and work-related diseases. Work-related mortality is presented in Figure 5.4.

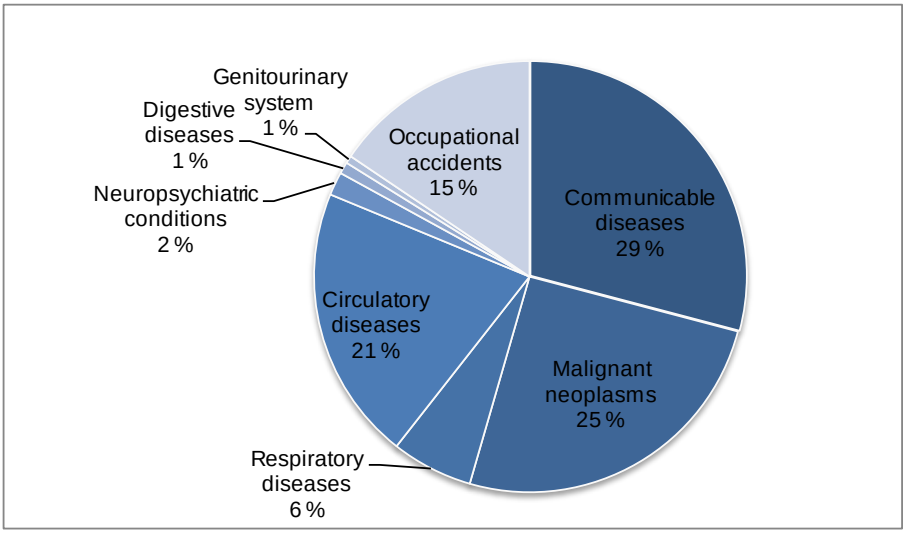


Figure 5.4. Global estimated work-related mortality by cause in 2002

The three biggest disease groups are communicable diseases (29%), malignant neoplasms (25%), and circulatory system diseases (21%). The proportion of occupational accidents has remained at 15% of all work-related deaths.

In 2003 fatal occupational accidents still slightly increased to 357,900 deaths. Non-fatal occupational accidents clearly increased to 330 million occupational accidents causing at least 4 days' absence. The number of fatal work-related diseases remained almost the same, but deaths caused by dangerous substances increased remarkably to 650,000 deaths (Table 5.4).

Table 5.4.Number of occupational accidents in 2003 and fatal work-related diseases in 2002 at regional level

		Occupational accident causing at least 4 days' absence				
Region	**Fatalities**	**Lower limit**	**Upper limit**	**Average**	**Fatal work-related diseases**	**Deaths caused by dangerous substances**
AFRO D	31,843	24,494,514	35,380,965	29,937,739	118,849	39,794
AFRO E	23,646	18,188,948	26,272,925	22,230,937	241,510	80,864
AMRO A	8,723	6,709,903	9,692,083	8,200,993	96,185	32,205
AMRO B	27,833	21,409,936	30,925,464	26,167,700	84,935	28,439
AMRO D	2,616	2,012,476	2,906,909	2,459,693	19,718	6,602
SEARO B	23,925	18,404,167	26,583,797	22,493,982	89,534	29,978
SEARO D	69,510	53,469,423	77,233,611	65,351,517	428,339	143,420
EURO A	5,298	4,075,466	5,886,784	4,981,125	139,519	46,715
EURO B	7,176	5,519,930	7,973,232	6,746,581	56,881	19,045
EURO C	9,091	6,992,759	10,100,652	8,546,706	122,128	40,892
EMRO B	5,468	4,206,352	6,075,842	5,141,097	20,395	6,829
EMRO D	17,438	13,413,584	19,375,177	16,394,381	85,738	28,708
WPRO A	2,370	1,823,292	2,633,644	2,228,468	45,745	15,317
WPRO B	123,011	94,623,997	136,679,107	115,651,552	395,638	132,471
WORLD	357,948	275,344,749	397,720,193	336,532,471	1,945,115	651,279

Communicable diseases form over 60% of all work-related diseases, including occupational accidents in AFRO regions. Also in AMRO D and SEARO regions communicable diseases are quite a big problem. In developing regions the other main disease group is circulatory diseases, the proportion of which is circa 40% in EURO B and C as well as EMRO regions. Malignant neoplasms are especially a burden in developed regions. In all developed regions (AMRO A, EURO A and WPRO A) they comprise over 50 % of all regional mortality. Circulatory diseases are the second largest cause of death. In these regions the proportion of occupational accidents is the lowest. (Figure 5.5)

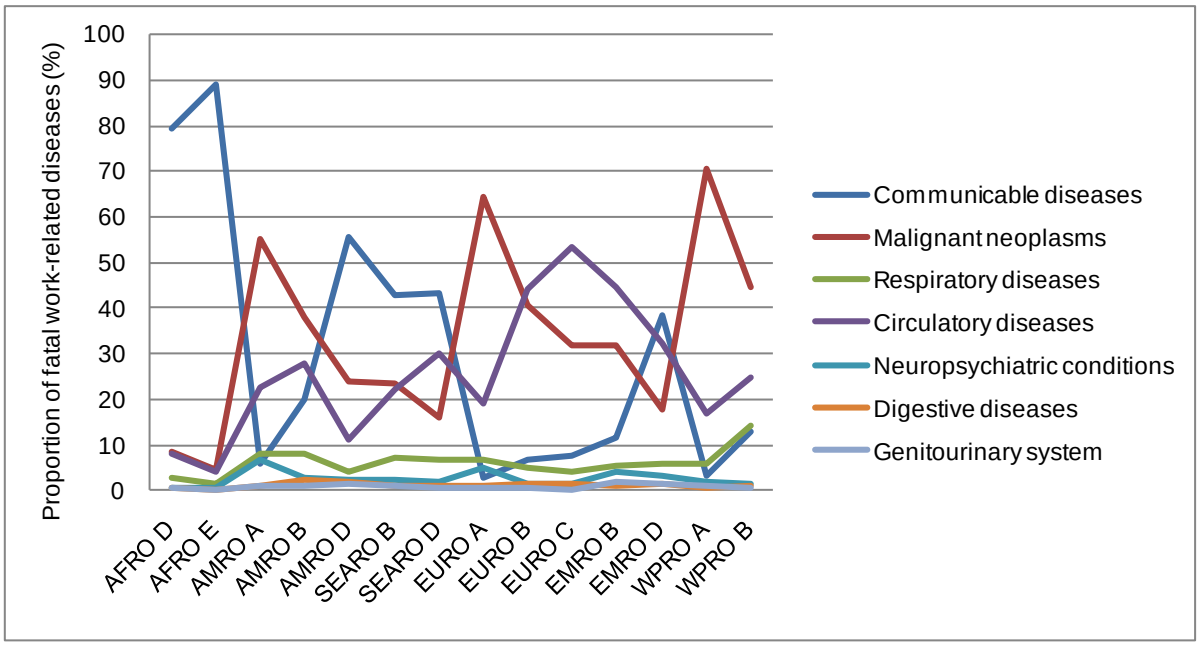


Figure 5.5. Proportion of fatal work-related mortality by cause at regional level

When considering fatal work-related diseases by gender and age, communicable diseases by women aged 15 to 44 dominate. Communicable diseases are usually acute, having a short incubation time. Other fatal work-related diseases are discovered later, mainly aged 45 to 70 years. This also indicates a long latent period or long time needed for the disease to develop (Figure 5.6).

In both genders cancers and circulatory diseases are the other main diseases causing death; other deaths because of work-related disease are marginal at the global level. An exception is respiratory diseases, which are a clear cause of death for men. (Figure 5.6)

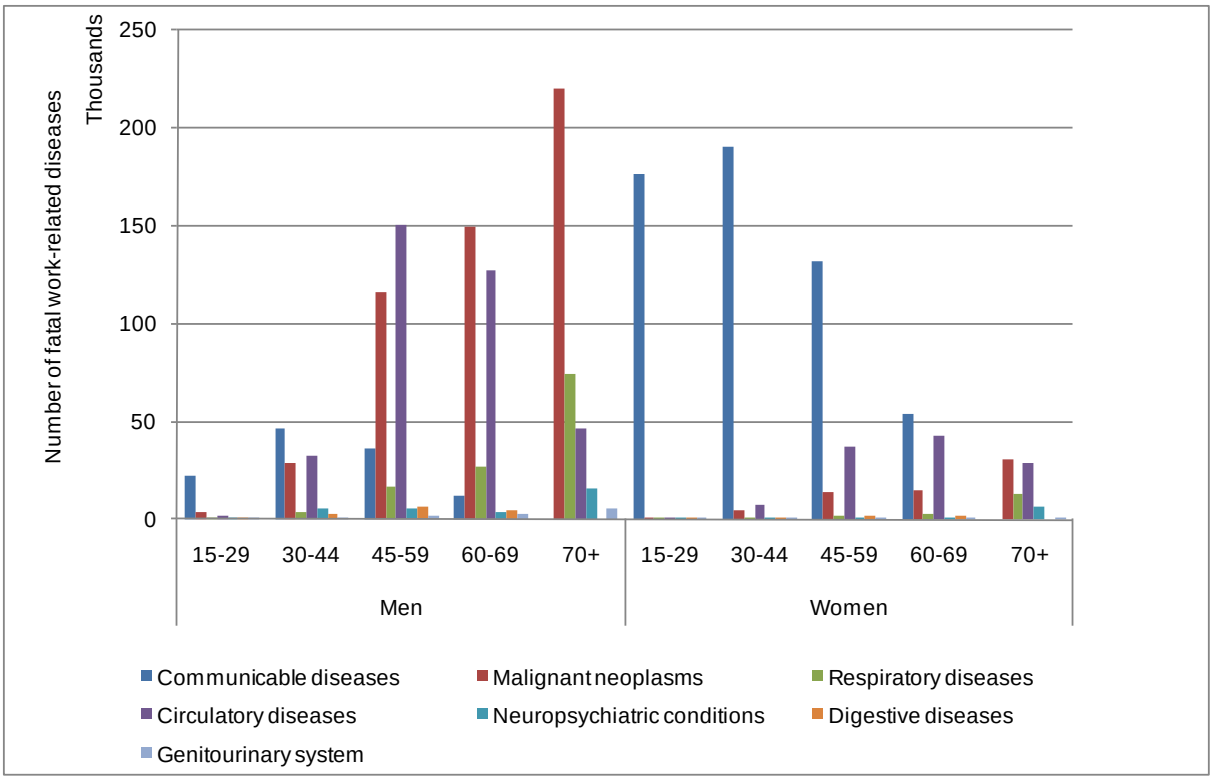


Figure 5.6. Fatal work-related diseases by gender and age

5.4 Trend of occupational accidents and fatal work-related diseases

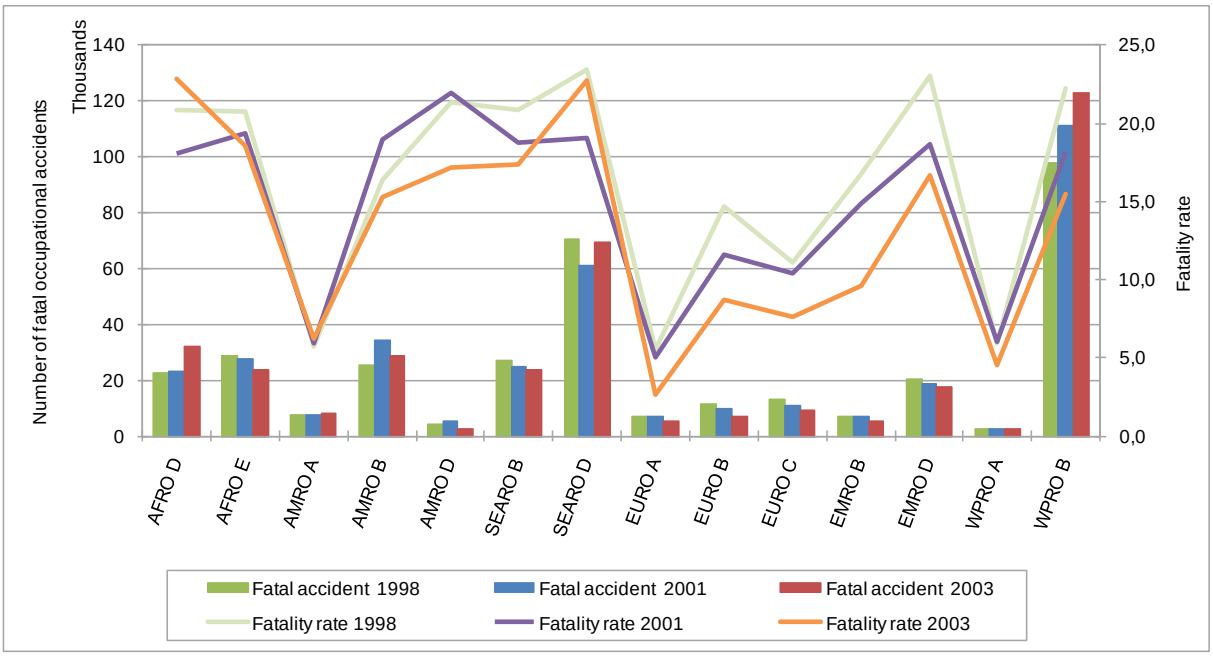
The total number of fatal occupational accidents and fatal work-related diseases occurring yearly is approximately 2.3 million (Table 5.5). This means that every day 6,300 workers are dying because of work.

Table 5.5. Trend of occupational accidents and fatal work-related diseases

Year	Fatal occupational accidents	Fatality rate	Occupational accident causing at least 4 days' absence	Accident rate	Fatal work-related diseases	Year
1998	345,436	16.4	263,621,966	12,534	2,028,003	2000
2001	351,203	15.2	268,023,272	12,218	1,945,115	2002
2003	357,948	13.8	336,532,471	12,966		

Occupational accidents which cause at least four days' absence from work have increased by 20% during a five year period (Table 5.5). This means that in 1998 there were 720,000 occupational accidents per day, but in 2003 approximately 920,000 occupational accidents causing at least 4 days' absence. Fatal work-related diseases have remained quite the same. It is noticeable is that the estimated period was short - two years. (Table 5.5)

Although the number of fatal occupational accidents has increased at the global level, the fatality rates per 100,000 workers have decreased. In 1998 the fatality rate was 16.4 and in 2003 it was 13.8. (Table 5.5). Fatality rates have decreased in most regions. The decrease is quite strong in EURO and EMRO regions as well as in SEARO B and WPRO B regions. In other regions the fatality rates have remained quite the same for six years, except in the AFRO D region, where the fatality rate has clearly increased. It is interesting that the total number of fatal occupational accidents has increased considerably in the WPRO B region and still the fatality rate per 100,000 workers has also decreased considerably (Figure 5.7).



Africa (AFRO), Americas (AMRO), South-East Asia (SEARO), Europe (EURO), Eastern Mediterranean (EMRO), Western Pacific (WPRO)

Figure 5.7. Number of fatal occupational accidents versus fatality rate in different regions

Although the number of occupational accidents causing at least 4 days' absence from work have increased by over 20% during five years, the occupational accident rate has increased only slightly, with 12,900 occupational accidents per 100,000 workers in 2003 (Table 5.5). Occupational accident rates are highest in AFRO D and SEARO D regions, being in both regions about 21,500 accidents per 100,000 workers. In other regions the rate has mainly decreased. (Figure 5.8)

Global changes in the economically active population and total employment affect the estimates of the number of occupational accidents and rates. If the number of economically active population or total employment increased, so the accident rates presented in Table 4.2 and 4.3 also increased. Thus, the estimated number of occupational accidents increased also. On the other hand, increased employment figures also affect the fatality rate and occupational accident rate.

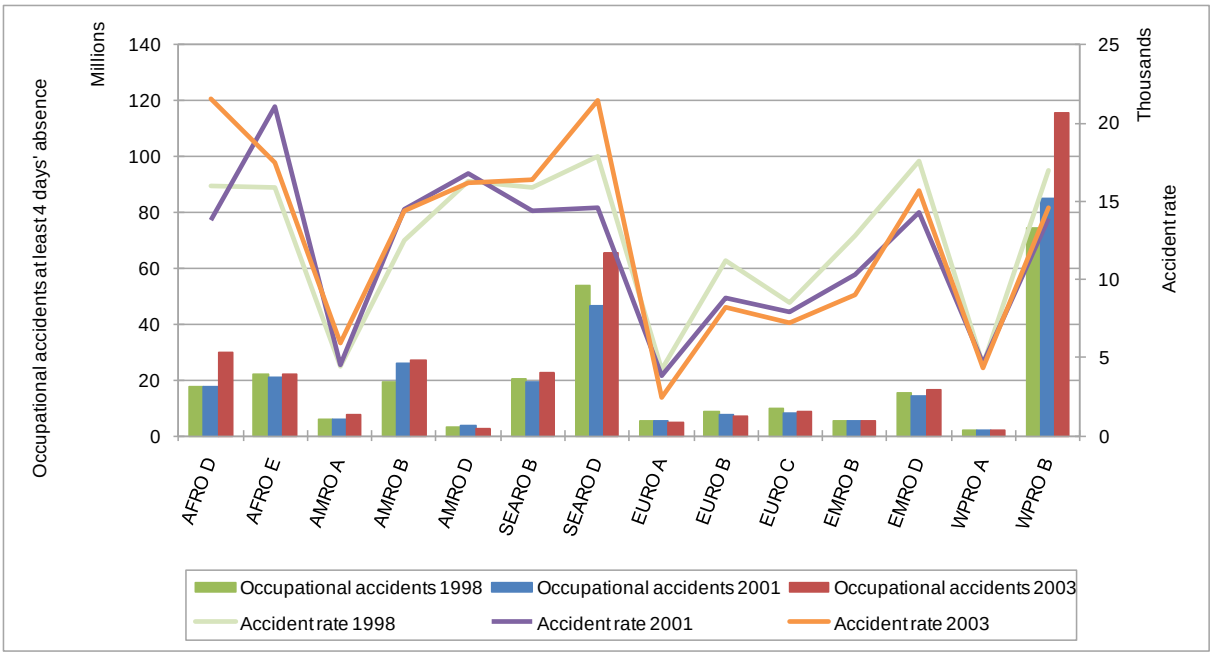


Figure 5.8. Number of occupational accidents causing at least 4 days' absence from work versus occupational accident rate in different regions

During a five-year period the number of economically active population has increased only slightly, but the figure for total employment may vary between different regions (Figure 5.9). The figure for total employment is a more accurate, but it can be used only in the calculation with developed regions. Especially in both AFRO regions and SEARO D region the total employment figure at the country level is often missing (see Paper IV). This means that the estimated numbers of occupational accidents are underestimations for almost all developing regions, and also the fatality rate and occupational accident rate are too low for these regions. (Figure 5.9)

The number of fatal work-related diseases has remained almost the same worldwide, but the study period is quite short. When studied more carefully, only in region EURO A have fatal work-related diseases remained almost the same during two years; in other regions the numbers of fatal work-related diseases have increased or decreased quite much (Table 5.6).

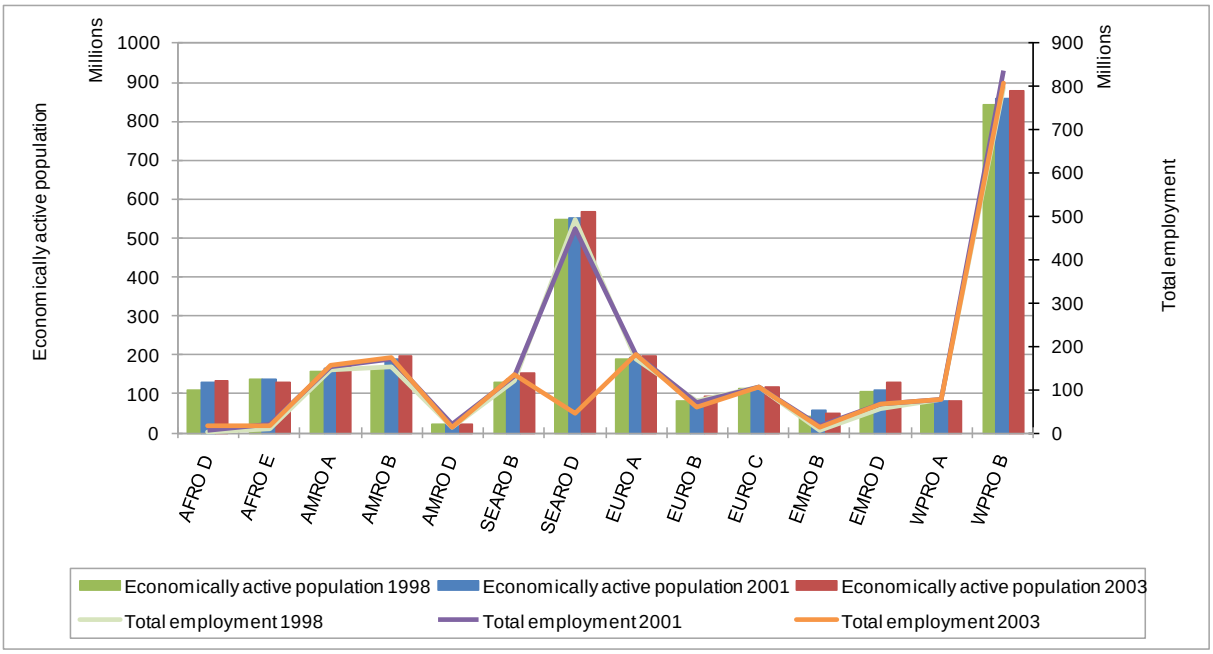


Figure 5.9. Number of economically active population and total employment during a five year period in different regions

In AFRO D, EURO B and EMRO B regions the number of fatal work-related diseases has decreased by circa 30% (in EMRO B more than 50%). In AMRO D and EURO C regions respectively the number of fatal work-related diseases has increased by over 20%. In the rest of the regions fatal work-related diseases have increased or decreased by at least over 10%. (Table 5.6)

Table 5.6. The number of fatal work-related diseases at regional level

	Work-related diseases	
	2000	**2002**
AFRO D	170,911	118,849
AFRO E	198,436	241,510
AMRO A	109,173	93,726
AMRO B	102,745	87,394
AMRO D	13,383	19,718
SEARO B	72,259	89,534
SEARO D	374,647	428,339
EURO A	133,916	139,519
EURO B	80,317	56,881
EURO C	97,013	122,128
EMRO B	46,254	20,395
EMRO D	98,600	85,738
WPRO A	55,780	45,745
WPRO B	474,570	395,638
WORLD	2,028,003	1,945,115

Circulatory diseases, communicable diseases, malignant neoplasm and occupational accidents are the main cause of death from all work-related deaths. They form over 90% of all fatal work-related deaths. The proportion of the cause of fatal work-related diseases has remained almost the same (See Paper II and V).

Communicable diseases are still a major problem in developing countries, but the proportion of all fatal work-related diseases has very slightly decreased (Table 5.7). Although the number of deaths due to neuropsychiatric conditions is low (2%), it has slightly increased during the two-years in question. It can be assumed that the number of deaths due to neuropsychiatric conditions will increase in future. These diseases, together with musculoskeletal disorders, are the main disease groups in developed countries, causing absences from work and leading to disability pensions. The other usual fatal work-related disease group is cancers. The proportion of work-related cancer (malignant neoplasm) from all fatal work-related diseases has decreased. However, the decrease is slight (3%). Respiratory diseases remain the same and are especially a problem in China (see Paper II). The estimates of work-related diseases cover only deaths. A bigger problem in many countries is musculoskeletal disorder and mental disorders, which do not cause deaths, but a lot of absences from work. (Table 5.7)

Table 5.7. Fatal work-related diseases by gender and cause

	Total		Men		Women	
	2000	**2002**	**2000**	**2002**	**2000**	**2002**
Communicable diseases	625,660	670,487	108,256	117,415	517,404	553,072
Malignant neoplasms	634,984	583,720	570,008	518,533	64,975	65,187
Respiratory diseases	144,788	140,397	127,226	121,759	17,562	18,638
Circulatory diseases	449,343	476,587	337,129	359,900	112,214	116,687
Neuropsychiatric conditions	24,212	40,464	18,827	31,944	5,384	8,520
Digestive diseases	21,266	20,301	16,307	14,872	4,959	5,429
Genitourinary system	10,362	13,159	9,163	11,736	1,200	1,424
Occupational accidents	345,719	357,948				
Total mortality	2,256,335	2,303,063	1,186,917	1,176,159	723,699	768,956

Approximately one third of fatal work-related diseases occur among women (Table 5.7), but it is believed that this proportion will increase in the future. Besides men representing a higher proportion of the workforce, they have traditionally worked in occupations needing a heavy physical workload. Men also more often work in occupations classified as hazardous jobs. Worldwide, women´s participation in work is increasing and will show in the records after some years.

Different diseases are also divided differently for men and women. Whereas communicable diseases are mainly a women's problem (over 80% of all communicable diseases), men

suffer almost 90% of all fatal work-related cancers (malignant neoplasms). Women are working in jobs like agriculture, nursing, and food processing, where the risk of infection is greater than for men. Otherwise, the proportion of fatal work-related diseases for men and women is almost identical (Table 5.7). See also Paper II and V.

5.5 Effect on globalisation and competitiveness

It is difficult to prove the effect of globalisation on occupational safety. In developed countries, statistics seem to show that occupational accidents may have decreased at least partly because of globalisation. The flow of industrial production to developing countries has increased and the increase is still continuing. The decrease in the number of fatal occupational accidents and also the fatality rate per 100,000 workers in Europe and the USA may be explained by globalisation. Competition from developing countries has been blamed for increased wage losses in the USA and for causing unemployment in Europe (Neumayer and De Soysa 2005). Also, the demands for effectiveness and mergers have decreased occupational accidents in developed countries.

In developing areas, the effects of globalisation on occupational accidents are clearer. Extensive industrialisation causes accidents, but it also increases consciousness of occupational safety and health issues. At least a small part of the increase in occupational accidents in developing areas is due to better recording and compensation systems and an increase in the number of safety and health rules. It appears that industrialisation that involves the building of roads, infrastructure and telecommunications, factory construction, increased traffic and the use of untrained workers in totally new tasks increases the number of fatal and other accident rates rapidly.

Globalisation has affected the flow of migrants: the flow from Asia, Africa and South America to North America and Europe. The more developed regions received 104.1 million migrants in 2000 (Global policy forum 2006). Migrant workers are divided into two groups: highly educated and skilled workers, both from developed and developing countries, and unskilled migrants from developing countries. Occupational accidents occur more typically in the case of unskilled workers than skilled ones. Also in developed countries, part of the migrants are working in the informal sector, where workplace health risks are high (Glodstein et al. 2001). Occupational accidents that happen to migrants do not always show up in official occupational accident records. However, the situation regarding migration flow is changing. An increasing number of migrants are moving inside their own region (Facci 2002; Workers on... 2006). For example, in Asia, earlier 90% of migrants found jobs outside of the region, whereas in recent years 40% of migrants have gone to other Asian countries (Workers on... 2006). See Paper III.

The competitiveness of one country in relation to other countries can be seen as one part of globalisation. Many factors affect competitiveness and it is also measured in different ways. GDP, which, however, is not able to explain work-related mortality, serves as one indicator. The dependency of work-related mortality per 100,000 workers on GDP per capita was analysed. The analysis was done using the regional mortality rate as the dependent variable. R2 is only 37% and it is not statistically significant (p=0.197).

However, the dependency of fatal occupational accidents per 100,000 workers, which is explained by the GCI, was statistically significant, having the p value <0.001 and R2 equal to 57% (Figure 5.10). The GCI for 125 countries produced by the World Economic Forum was used. The result of variance shows that the GCI is dependent on the region (F=25.3 and p<0.001).

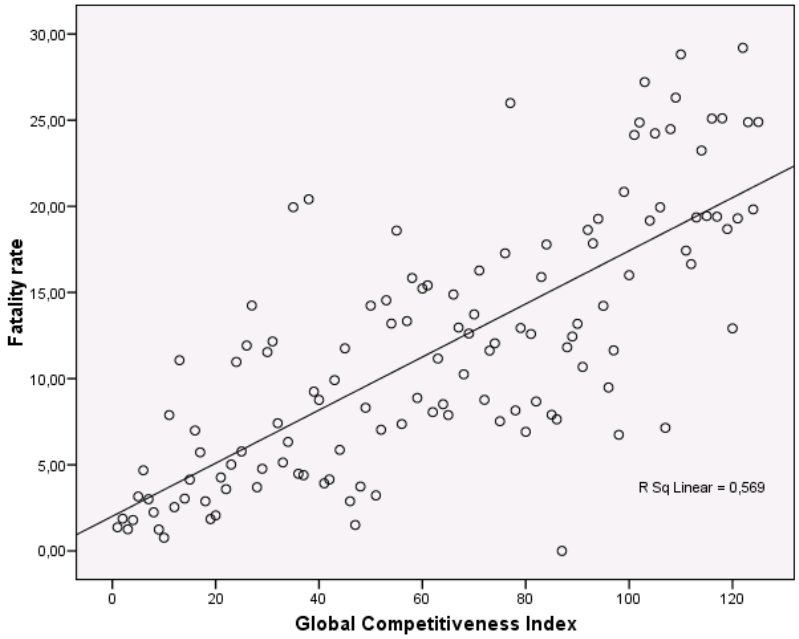


Figure 5.10. Dependency of fatal occupational accidents on GCI per 100,000 workers.

Competitiveness and occupational fatality rate were described using country level graphs by regions. Figure 5.11 shows as an example the competitiveness and the number of fatal occupational accidents in Europe. In other regions the results are almost the same; the better competitive ability a country has, the lower is the fatality rate (see also Paper VI).

All countries in Sub-Saharan Africa have quite high fatality rates and they also have the highest GCI. In the American region, the USA and Canada clearly have a lower fatality rate and GCI than countries in Central and Latin America. The fatality rates slightly increase when the GCI increases. The Eastern Mediterranean region's competitiveness and fatality rates seem to be in step with each other. The World Economic Forum has ranked established

market economies in Asia quite high on its GCI ranking list. It is noteworthy that also new market economies, such as India and China, have quite a good index position.

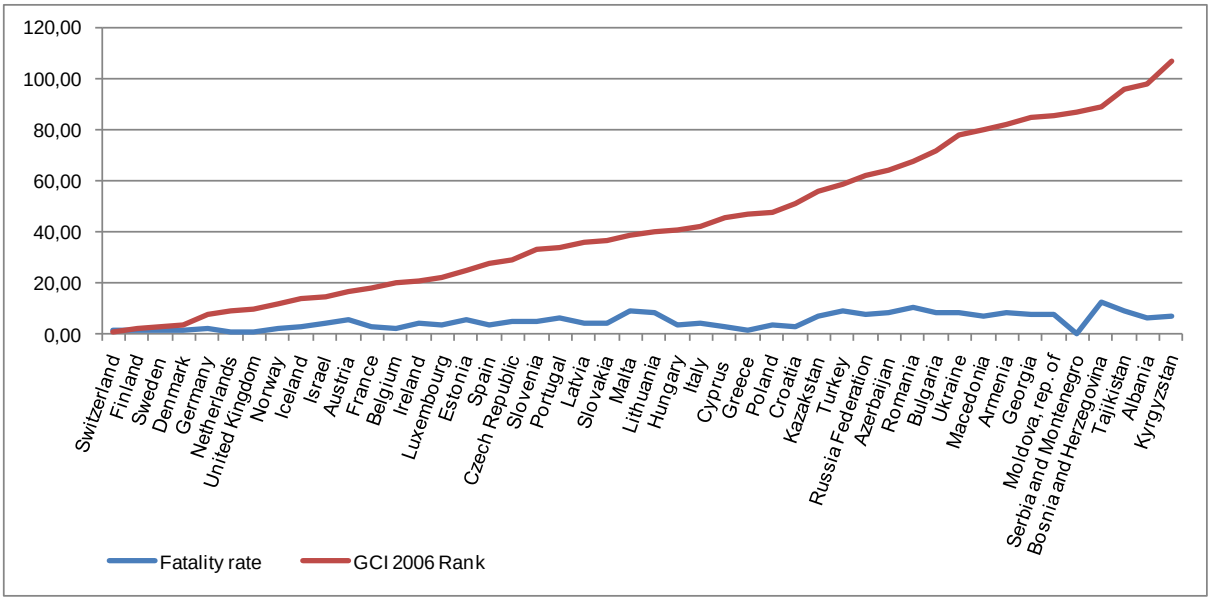


Figure 5.11. Competitiveness and occupational fatality rate in Europe.

Competitiveness in Europe at the country level is very strong and the fatality rates are quite low. EU countries obtained the highest ranking compared with other regions. However, Europe is not a unified region and competitiveness between countries varies considerably, as it varies also in other regions.

If only EU-25 countries are considered, in all of them the fatality rate is under 10, and for most of them under 5. Competitiveness is high: the first four countries in terms of degree of competitiveness are EU countries and all 25 EU countries are placed among the 48 most competitive countries.

6. DISCUSSION

6.1 Global burden of occupational accidents and fatal work-related diseases

New estimates of work-related accidents and diseases show that work is much more prone to risk than has been previously understood. According to the estimates, annually more than 2.3 million people die because of fatal occupational accidents or work-related diseases. This means that every day over 6,000 people die of these causes. Also, more than 900,000 workers a day get hurt at work. Over a ten-year period both occupational accidents and fatal work-related diseases have increased. Especially, fatal work-related diseases and occupational accidents which cause at least 4 days' absence have increased considerably. When in 1994 Leigh et al. (1999) estimated that 700,000 workers die because of work-related diseases, in 2002 the estimate was twice as great, being near to 2 million. The average figure for occupational accidents was estimated to be three times greater in 2003, being more than 300 million.

However, occupational accident rates, both fatality rate and non-fatal accident per 100 000 workers, have decreased or remained quite the same in the study period. This does not necessarily mean that the occupational safety and health situation is improving worldwide. The total employment figures were missing for most of the countries in the AFRO, SEARO, EMRO and WPRO B regions. Instead, the figure for the economically active population was used. This decreases the rates because the economically active population also contains unemployed persons.

Fatal work-related cancers (25%), circulatory diseases (21%) and communicable diseases (29%), as well as fatal occupational accidents (15%) are the main work-related burden globally. Work-related cancers and circulatory diseases are the main concerns in developed areas, while communicable diseases are of concern in developing areas. In the case of communicable diseases, it is believed that they will decrease when developing countries´ social, technical and economical development increase (Andersson 1999 p. 27). The number of occupational accidents, fatal and non-fatal, are decreasing in developed regions and mainly increasing in developing regions.

6.1.1 Achievement of objectives

The objectives of this study have been multidimensional. Estimates had to be arrived at because information on occupational accidents was lacking or missing, and especially figures on fatal work-related diseases were missing. The estimates will hopefully help countries to provide a better understanding of the importance of occupational health and safety at country and company level. Strong industrialization and urbanization have increased work-related health and safety problems, but the awareness of workers is, in general, also increasing (Anton 1989 pp. 372-381). Occupational safety and health management will benefit from this (Shahnavaz 1987). Good safety management is based on the prevention of accidents (Kjellén 2000 p. 31).

The main objective of the study was to create models to estimate the global number of occupational accidents and fatal work-related diseases. The objective was achieved, but the results highlighted several questions affecting the issue, such as age, gender, stress, child labour, chemicals used at country level, globalization, migrants, immigrants, education, awareness of safety and health, etc. All the questions mentioned above affect each other and affect the number of occupational accidents and work-related diseases, but when making estimates all of these issues could not be taken into account. Achievement of the objective meant also that some generalization had to been made (see 6.2.3). This was mainly because of the lack of statistical information (see 6.2.2).

6.1.2 Relation to previous studies

Quite soon after the Industrial Revolution it became clear that the prevention of work-related harm needed information about occurring occupational accidents and diseases. Official statistics were collected and used for accident prevention in particular countries. Studies were concentrated on a single country, which at the time was understandable. Global or regional comparisons have been made mainly in the last couple of decades, when the compilation of the statistics has improved; e.g. the European Union (EU) collects occupational accident data from their member countries. However, even if the information gathered from member countries should be the same, the definitions and coding systems vary between countries. The number of fatal occupational accidents is thought to be reliable, but even here there are different kinds of rules included in the statistics mainly with relation to time limit. For example, the Netherlands registers occupational accidents as fatal when the victim dies the same day and Germany if the victim dies within 30 days. Some countries have no time limit and some have a one-year time limit. Also, occupational accidents other than fatal ones are corrected in the case of some member countries. For example, the average reporting level in Denmark is 46%, in Greece 39%, in Ireland 38%, in Sweden 52% and in the United Kingdom 43%. (European statistics on… 2001 p. 25, 27)

Several articles are available which cover work-related injuries and diseases in different countries, regions, or business sectors. The background to these studies is usually that official figures are missing or lacking. (e.g. Ooteghem 2006; Liu et al. 2005; Dong & Platner 2004; Leigh 2004) Lack of published data on occupational accidents and work-related diseases is the case also in many developed countries. Leigh et al. (1997) have estimated that in the USA, 66,822 work-related deaths from diseases and injuries occur annually. This is quite a lot more than official figures show. Another study from the USA estimates that 55,254 fatal occupational diseases and injuries occur annually (Steenland et al. 2003). In Finland, approximately 1,810 deaths happen each year related to work (Nurminen and Karjalainen 2001), when the official figures show less than 200 fatal occupational accidents and diseases (Occupational... 2007). The estimated number of deaths that occurred each year in Australia from occupational exposure to hazardous substances was 2,290 (Morrell et al. 1998). However, this does not cover all work-related hazards in Australia. In addition, research concerning estimates of occupational accidents and work-related diseases has been done mainly for developed countries and adapted for developing countries.

In recent years several articles have been published discussing the number of occupational accidents and work-related or occupational diseases in developing countries or countries under industrialisation. Most of them discuss the current situation in a specific country, examining sources not used before: as in Botswana (Ooteghem 2006), China (Liu et al. 2005), Malaysia (Abas et al. 2008), Thailand (Thepaksorn et al. 2007) and Turkey (Unsar and Sut 2009). In the same way most of them recognised the problem caused by under-reporting (Abas et al. 2008; Ooteghem 2006; Thepaksorn et al. 2007; Werner 2000). Some of the studies are estimates of the number of occupational accidents and diseases because official numbers are missing or clearly under-reported, as in Ghana (Mock et al. 2005), Uganda (Kobusingye et al. 2001) and Vietnam (Marucci-Wellman et al. 2009).

Some international comparisons have been made, but these are available only for developed countries, which have data on occupational accidents and diseases. Spangenberg et al. (2003) compared the work-related injury rates between Denmark and Sweden on construction sites. The lost time injury rates for serious injuries and fatalities were quite the same for both countries, while with the rate for minor injuries they found a twofold difference. Feyer et al. (2001) compared work-related fatal injuries in the United States, Australia and New Zealand. They found that the differences between countries can result from differences in structural industry distribution. Nishikitani and Yano (2008) compared differences in fatal occupational accidents in OECD countries. They concluded that reported differences in lethality can reflect artificial administrative factors rather than the actual severity of occupational accidents.

The present study is the first to estimate the global number of occupational accidents and fatal work-related diseases at the country level. Comparisons can be made at country and regional level because the estimates are calculated in the same way in each country.

Nonetheless, Leigh et al. (1999) published the first global estimates of fatal occupational injuries and diseases, indicating that approximately 100 million occupational injuries (100,000 deaths) and 11 million occupational diseases (700,000 deaths) occur annually. Other research is by Takala (1999), who estimated that annually 1.1 million work-related deaths occur , comprising occupational accidents (335,000), commuting accidents (158,000), and occupational and work-related diseases (636,000). Newer global estimates have been published by Concha-Barrientos et al.(2005), estimating that approximately 312,000 fatal unintentional occupational injuries happen yearly.

In the field of work-related diseases, only a few global estimates have been made. Murray and Lopez (1996) give estimates for all diseases, not only work-related ones. The World Health Organization (WHO) has continued the Murray and Lopez work and published newer estimates of global diseases. Many other studies have been performed concerning work-related diseases, but they focus on separate symptoms like work-related stress, burnout and sleep disturbances (e.g. Costa 1996; Hotopf and Wessely 1997; Tennant 2001).

In a bigger perspective, WHO has estimated that in total 5.8 million people worldwide died in 1998 because of injuries - unintentional and intentional - and for every person who dies several thousand are injured, but survive (Krug et al. 2000). The authors suggest that 16% of diseases in the world can be attributed to injuries.

6.1.3 Relevance of the study in the field of occupational safety and health

Global estimates of occupational accidents and fatal work-related diseases are not created just to obtain estimates for all countries. The main purpose is to increase awareness of the global occupational safety and health situation. Different studies have shown that especially developing countries do not have enough resources, knowledge and competence to improve their occupational safety and health (LaDou 2003). Whilst in developed countries one tendency in the field of occupational safety has been proactive safety management and the capability to respond to regular and irregular threats (Hollnagel 2007), still many companies in developing countries have no familiarity at all with occupational safety and health. They do not have enough knowledge and skills and they do not understand the present level of safety.

The relevance of the study in the field of occupational safety and health can be assessed on the national level and global level. Worldwide countries can be roughly divided into three groups: (1) countries which are post-industrial societies, (2) countries which are just industrialising and turning into the category of developed country, and (3) countries which are still developing countries. The relevance of the study for countries in these groups is also different. From the perspective of post-industrial countries the main significance is probably providing information about the global situation. Even in many developed countries the

recording of occupational accidents and work-related diseases is lacking, and establishment of a new system for collecting and recording statistics is a challenging change to make. In these countries safety and health experts know the situation and the recorded statistics might be corrected. More challenging is how the statistics are given to policymakers and how the statistics affect the safety and health work in the country.

Countries under industrialisation are facing a new situation and awareness about safety and health has increased. This has affected occupational safety and health legislation, which has been renewed in many countries like South-Korea and China. However, the recording of occupational accident and work-related diseases is lacking and the real situation is very often unknown. In addition, many countries in this group still have labour-intensive agriculture which causes a lot of accidents. The study results for these countries are more meaningful and hopefully will affect their recording systems and practices. Based on the published articles, some inquiries about the number of occupational accidents and fatal work-related diseases have been received by the author. The inquiries have been mainly related to the methods used and the results. Especially experts in the safety and health field have been interested in the estimates. For developing countries the studies give estimates which they do not typically have at all. The estimates are a starting point for safety and health work.

Furthermore, the study results will hopefully affect attitudes in the long run globally. To achieve this aim, the combined efforts of nations and companies are necessary. From the global perspective, changes in social structure such as corporations merging, outsourcing and production flow to developing countries have made impact both in developed and developing regions on the number of occupational accidents and work-related diseases, even if this is difficult to demonstrate (See also Paper III). Multinational corporations may relocate labour-intensive and often more dangerous work to low-income countries where salaries are low and regulatory measures poor. From the safety management perspective this is seen as a decrease in occupational accidents and work-related diseases in developed countries and as an increase in those in developing areas. Sometimes the work materials and processes are dangerous and the environment may be dirty and infested with pests and microbes. Also, problems connected with space, lighting, ventilation or noise may be prevalent. Dangerous chemicals may be handled without taking precautions. (Glodstein et al. 2001; Phoon 2001)

Free trade as part of globalization has already led to a number of adverse occupational health impacts (Glodstein et al. 2001). It has affected labour conditions (including child and slave labour), expenditure of natural resources and environmental destruction, migration, social movement and injustice (Humphrei 2003; Palmowski 2003). Globalization has also led to an increase in deregulation and the informal sector, and poverty (Facci 2002; Holkeri 2002; Palmowski 2003). These effects and outcomes differ, depending on the region and country. Western Europe and the USA have benefited greatly from globalization. South East Asia has also gained (Humphrei 2003). Some parts of South America have gained, but

globalization has also aggravated many problems there (A fair globalization... 2004 p. 16, 17; Humphrei 2003). In Africa, the main problem is in the different industrial society. Rural and informal working populations are practically outside any protection measures. This applies to both legal and compensation coverage, as well as to inspection and occupational health service coverage. Africa has been seen as the only region where the effects of globalization have been mainly negative (A fair globalization... 2004 p. 4, 15). More flexible labour policies may lead to a weakening of commitment to occupational health and safety programmes (Neumayer and De Soysa 2005), and global competition may lead employers to view the prevention of occupational injuries and the protection of workers' health as a barrier to trade (Glodstein et al. 2001).

Another effect of the results might be increasing the comparison between countries. This might motivate better safety and health work, in particular because better safety and health increases competitiveness (See Paper VI). Competitiveness is highest in the countries where the fatality rate is lowest (Decent Work ... 2005 p. 14; Lopez-Claros et al. 2006 p. 14-23). However, competitiveness also depends on region. Those countries in which competitiveness is highest are developed, industrialized countries. Competitiveness requires political and economic stability as well as a well-trained labour force (Lopex-Claros et al. 2006 p. 3). Many enterprises in high-income countries are relocating their work to low-income countries which offer political and economic stability. In these countries (e.g. the Republic of Korea, Malaysia, Chile, and Thailand) productivity and competitiveness have increased and they have gained from globalization (Facci 2002; Palmowski 2003; Lopex-Claros et al. 2006 p. 32-34). Also, in many former socialist countries competitiveness has increased (see Paper VI). Workers' consciousness has increased and this usually leads to an improvement in occupational safety and health. Changes related to work, work conditions and work environment have an effect on, e.g. productivity, working climate, safety culture, and workers´ commitment. These are all factors which affect competitiveness at the company as well as country level. It appears that if countries wish to pursue higher competitiveness at the global level, they also have to put a stronger effort into safety management at the national as well as at the company level. Companies which have put effort into occupational safety and health have decreased their accident figures even down to zero, depending on their line of business. Another result has been better productivity, increased ability to work, and job satisfaction.

Therelevance of the study can be seen especially in the case of work-related diseases. Evidence concerning the under-reporting of occupational diseases (Eurogip-03/E 2002 p. 10; Spreeuwers et al. 2008) has strengthened the results regarding the increasing trend in fatal work-related diseases. Estimates are needed because work-related diseases have a strong impact on workers, enterprises and society (Kankaanpää et al. 2008). The combination of different exposures, daily exposure time, duration of use and heredity affect the incidence of work-related disease (Driscoll et al. 2005a; Leigh et al. 1999). In addition to the physical and psychosocial effects, the costs of work-related diseases are also considerable. Leigh et al.

(2003) estimated the medical costs of 14 occupational illnesses in the United States. They estimated these costs to be USD 14.5 billion. These costs do not cover all occupational illnesses, and do not include indirect costs. Leigh et al. (2006) later also estimated total costs - including medical costs, wage loss, household production loss and loss due to pain and suffering – to be USD 77 billion.

There are many factors contributing to work-related diseases in the workplace, and they have combined effects like psychosocial disorders and other possible outcomes, including: burnout, alcohol abuse, unexplained physical symptoms, absenteeism, chronic fatigue and accidents, sick building syndrome and repetitive strain injury (Hotopf and Wessely 1997). The estimates in the present study give only the number of fatal work-related diseases in seven main disease groups and exclude other diseases. However, they give guidelines for prevention purposes. For example, although the number of deaths due to neuropsychiatric conditions is low, it can be assumed that they will increase in future. These diseases, together with musculoskeletal disorders, are the two main disease groups in developed countries which cause absences from work and lead to disability pensions (Dewa et al. 2004; Eurostat 2008; Sroujian 2003). While musculoskeletal disorders are a well-studied area and the exposure and response relationship is well understood (Marras et al. 2009), there is no clear consensus on how various factors affect mental health (Dewa et al. 2004; Vézina et al. 2004). However, the link between mental illness among workers and work-related stress is clear (Dewa et al. 2004; Wang et al. 2006).

6.2 Study evaluation

The validity and reliability of the present study can be criticised because quite many assumptions had to be made during the study period. However, these assumptions were necessary by reason of missing or lacking information and the need for global estimates. It was attempted to ensure the validity and reliability of sources by using known and trusted sources maintained by a known party. As Robson et al. (2001 p. 55) indicate, existing injury data may involve reporting bias and under-reporting can be a significant source of bias; in addition, misclassification errors can cause problems in injury statistics.

Overall the validity and reliability of the study is quite dependent on the validity and reliability of the used data. It is better to use information from industrialised countries to obtain estimates than wait for reliable information from developing countries. Furthermore, the estimates made in this study are probably at the moment the most reliable figures worldwide, as Driscoll et al. maintain (2005a). Although the estimates include many inaccuracies, they are at the moment the only estimates worldwide that have been produced at the country level.

6.2.1 Internal validity

Internal validity means that a theory, model or concept describes reality accurately (Järvinen 2004 p. 157), and a valid method means that the researcher measures what he or she has hoped to measure (Robson et al. 2001 p. 52). In the present study two models were created to estimate the number of occupational accidents and fatal work-related diseases. Methods to create models can be criticised because estimates can be achieved in different ways. The models were constructed such a way that each country's own information was used when possible. This information could only be found, however, for the number of economically active population. The validity of using regional division and selection of representative country can also be questioned. But it was seen as the only way at the time to calculate estimates for all countries, partly because of research time limitations. The regional divisions are based on the geographical and economic divisions of the World Bank, and geographical and adult and child mortality from the WHO divisions. Even if countries are located in the same area and have the same religion, they do not necessarily have the same political and economic situation. Even though countries are quite different from each other, one country is used to represent a whole region. This affects the validity of study, but it was seen as a better approach than to use information on developed countries, which has been previously typically the case.

Another question which should be considered from the validity point of view is the use of global burden data and attributable fraction. Global burden data covers all diseases and not only work-related ones. Nevertheless, its use is justified because it was the only global data found at the time and this is still the case. Another weakness is that the attributable fraction used is based on information for industrialised countries. However, this information is most accurate and covers all main disease groups used in estimates of the global burden of diseases. Other studies giving an attributable fraction for occupational diseases can be found, but they are also for industrialised countries. In Appendix 1 a comparison is made between different attributable fractions (see also Paper II and V). The main problem in using the attributable fractions of other studies was that they do not cover all the main work-related disease groups. In addition, they give only a combined attributable fraction (Leigh et al. 1997), either combined or separate fractions for men and women (Steenland et al. 2003), or a limited attributable fraction (Morrell et al. 1998). Moreover, even though studies are mainly carried out in developed countries, the human metabolism and response is the same around the world.

The use of the term occupational accident instead of occupational injury can be criticized. The choice was based more on the use of the term in Finland and in Europe rather than a thorough consideration in the first place. During the period of the study it became clear that a better term would have been occupational injury. However, the term was not changed during the study because that might have caused confusion. In addition, no worldwide agreement on the term describing harmful occurrences at the workplace can be found. Some safety

researchers thought that the term accident should be banned, because its definition as unwanted, unplanned and uncontrolled refers to an unpredictable and unpreventable event, while the term injury is more well-defined, giving the promise of being preventable (Langley 1988; Loimer et al. 1996). However, Andersson (1999 p. 17) claimed that these two terms are not interchangeable, since they clearly refer to separate phenomena. He pointed out in addition that better definitions and interpretations of the essential concepts accident and injury are needed. He argued that very little has happened in terms of injury definitions since the energy model was presented. Example of this are musculoskeletal disorders, which can be considered an injury in some places but elsewhere it is a disease; or a sudden back pain is an injury but a heart attack is not. (Andersson 1999, p. 35) See also 2.1.1.

6.2.2 Reliability

Reliability is normally understood in terms of how different researchers studying the same phenomenon with similar purposes will get the same results (Hernon and Schwartz 2009; Järvinen 2004 p. 157). While validity concentrates on how well the methods measure what they are supposed to measure, reliable methods give consistent results on numerous occasions (Robson et al. p. 52). In the present study the main weakness in the estimated number of occupational accidents and fatal work-related diseases is the reliability of the statistics used as initial sources. The reliability of the methods used as well as the reliability of the results is concentrated on the reliability or unreliability of the used data.

In the case of the estimation of occupational accidents, it can be quite sure that different researchers will get the same results as the author has got. However, the final estimates might vary from the results of the present study if other researchers think that the representative countries are not the best ones to represent whole region and choose another country. This is a matter of the selection process more than a question of the reliability of the method.

Estimations of occupational accidents are mainly based on the information from the ILO. The proportion of reported accidents is very low (only 3.9%), and this varies between different continents and countries. Even countries in developed regions like the European region do not report all their cases (European statistics... 2001 p. 27). The number of fatal occupational accidents for insured/covered workers is the basis for the calculations, and this figure is probably lower than the real number. For that reason the selection of representative country was rejected. The estimated fatalities and the average figures shown may be lower than the genuine situation.

While fatal occupational accident figures can be found for some countries which were used to represent a whole region, information on occupational accidents which caused at least 4 days' absence cannot be found for those countries. In many developing countries, only a

couple of branches belong to that group. For that reason the proportion of fatalities and non-fatalities based on information from developed countries was used. Although there is a problem with using the proportion of fatal and non-fatal occupational accidents from developed countries for developing ones, it was seen as the only possibility to obtain estimates. Furthermore, the number of occupational accidents causing at least 4 days' absence from work is probably underestimated (Table 6.1). Especially those countries (Finland, France, Germany and Luxemburg) whose accident proportion was used in deciding the upper limit have more occupational accidents (France near average) than the estimate suggests. It can be seen that the upper limit is nearer the official one. Also, the estimates for Denmark and the United Kingdom are much lower than the official figures they have given to the EU. The upper limit cannot offer a real estimation for all countries. Also, a weakness in using limits is that if a country in any particular year has for some reason more fatal occupational accidents than usual, the number of occupational accidents causing at least 4 days' absence increases. This is probably the case with Austria, where the number of occupational accidents causing at least 4 days' absence is probably nearer 100 000 than 200 000.

Table 6.1. The estimated number of occupational accidents versus occupational accidents reported to the EU

	Estimated numbers of occupational accidents causing at least 4 days' absence			
Country	**Lower limit (0.13) 2003**	**Upper limit (0.09) 2003**	**Average 2003**	**Occupational accidents reported to EU in 2003** (Eurostat 2006)
Austria	174,615	252,222	213,419	88,792
Belgium	64,615	93,333	78,974	77,807
Denmark	39,231	56,667	47,949	62,076
Finland	37,692	54,444	46,068	58,504
France	601,538	868,889	735,214	710,282
Germany	693,077	1,001,111	847,094	1,040,303
Greece	52,308	75,556	63,932	36,150
Ireland	61,501	88,834	75,167	21,547
Italy	762,308	1,101,111	931,709	599,708
Luxembourg	5,385	7,778	6,581	11,305
Netherlands	80,000	115,556	97,778	69,240
Spain	555,385	802,222	678,803	792,565
Sweden	43,077	62,222	52,650	51,387
United Kingdom	172,308	248,889	210,598	399,763
Total	**3,343,040**	**4,828,834**	**4,085,936**	**4,019,429**

The estimated number of occupational accidents does not include commuting accidents. Nonetheless, some countries include commuting accidents in occupational accidents, while others do not. This caused some inaccuracies for the estimates. The same situation applies to the case of self-employed persons. Quite often accidents that occur for self-employed

persons are not included in the official records at all. This may be another reason for lower official occupational accident figures.

In the case of fatal work-related diseases the method used to obtain estimates can be questioned. It is, however, difficult to get estimates, because country base data worldwide is almost totally missing. The starting point for the estimates was somehow clear in the beginning of the study: use of information from the World Bank and the WHO global burden of diseases. The reason why the attributable fraction of Nurminen and Karjalainen (2001) was chosen for use at the beginning was that the attributable fraction for disease groups is based on several sub-group fractions, depending on the disease. The studies presented in Appendix 1 show that mainly for malignant neoplasms, i.e. cancers, more specific fractions can be found. Steenland et al. (2003) calculated the attributable fraction for nine separate cancers which form the attributable fraction of the whole cancer group, while Rushton et al. (2008) calculated the attributable fraction for six separate cancers. Nurminen and Karjalainen (2001) calculated the attributable fraction for cancer combining 28 different cancer groups. Also the attributable fractions for asthma, chronic obstructive pulmonary diseases (COPD) and pneumoconiosis are given. Communicable diseases are typically not given. While the attributable fractions of Nurminen and Karjalainen are typically higher than the fractions of other studies, the sub-group fractions are close to each other (Appendix 1).

Furthermore, developing countries are facing increasingly the same work-related diseases as developed countries (Andersson 1999, p. 27). This health transition has been tested in longitudinal studies and the results indicate this to be true (e.g. Ahmed and Andersson 1999; Plitponkarnpim et al. 1999a,b). So at some level the attributable fraction based on information from developed countries and used for calculating the number of fatal-work related diseases is acceptable.

Another question in the case of estimation of fatal work-related diseases might be regarding the inclusions and exclusions in diseases and age groups. In the case of disease groups, the inclusions and exclusions follow the inclusion and exclusion of the used attributable fraction which is justified. Also, clear disease groups in the data of global burden of diseases were rejected, as for example maternal and perinatal diseases. Some exclusions were made even if known that they might be work-related because the attributable fraction used excluded them, like for example cardiovascular diseases except ischemic heart disease, and cerebrovascular diseases. This might produce underestimations.

In the case of age groups, the selection was made partly in the same way as in the study by Nurminen and Karjalainen (2001). This is again justified. However, also included was age group 15-29, even though Nurminen and Karjalainen included only deaths occurring in persons aged 25-74. In developing countries even children under 15 are already working and quite often in dangerous sectors like agriculture, fishing, and mining. In addition, most of the disease groups were included for the age group 70+. This was because people in

developed countries are working longer and many diseases have a long latent period. Of course, it can be debated to what extent diseases are due to work, and to what extent due to other non work-related factors - at least in the over 70 age group. Life expectancy is clearly lower for those workers who are exposed to various kinds of hazardous substances or situations in the workplace.

The most critical consideration relates to estimates of fatal communicable diseases. A range is hard to find, because the attributable fraction used for communicable diseases was the only one that could be found at the time. In the case of communicable diseases it is also hard to know if a disease is really work-related or if it is an infectious disease from outside work, especially in developing regions (Negash 2002). Another aspect which affects not only communicable diseases but all work-related diseases is changes associated with work and leisure-time, e.g. physical exercise and eating habits.

Finally, the reliability of estimated number of fatal work-related diseases can be discussed. It is believed that the estimates are, however, rather underestimates than overestimates. Many diseases caused by work or the work environment are recorded wrongly. The health care staff do not have enough information about the history, skills and knowledge of the patients to identify the causes of the disease (Spreeuwers et al. 2008).

6.2.3 Generalization

This doctoral study is not an example of typical research in which the results are considered from a generalized perspective. The starting point of the study was the need for information which was not available on a wide scale. Peer review articles or available statistics were used. Consequently, the study method is also a generalization process. This is justified by the belief that findings can be generalized (Chapanis 1988). Chapanis (1988) suggested that “every study, whether basic or applied, can be generalized to some extent.” However, some issues related to the generalizing process in a study should be pointed out in the light of factors that limit generalization (Chapanis 1988):

- Internal versus external validity
- Unrepresentative subjects
- Inadequate training
- Inadequate sampling of situations
- Improper choice of dependent variables
- Long-term changes
- Measurement artefacts

Internal validity is essential when results are generalized. Because in this thesis the internal validity of the statistics used could not contribute, only peer review articles and known

sources were used. Unrepresentative subjects are the most obvious threat to external validity (Chapanis 1988). There are some aspects which should be considered more carefully because in this study these representative subjects have significant meaning for the estimated figures. To estimate the number of occupational accidents, representative countries were chosen. Selection was based on geographical division, economical and mortality data. Economic division was used in the regional division of the World Bank. The economic situation of the country probably better explains the number of occupational accidents than the mortality figures used by the WHO. However, geographical division is clearly a dominating factor, so the division based on mortality is not differential factor. In some regions a representative country used to calculate sectoral fatality rates may stress too much some sector which is not relevant to another country in the same region. This impact was decreased when using total figures for other countries. Marucci-Wellman et al. (2009) question this in their survey of work-related injuries in areas in Vietnam. They see that the generalization of findings to all of Vietnam would be unwise.

In the case of estimation of fatal work-related figures, the representative source was global burden data covering all diseases. The use of this was justified in that not only is it the only source for diseases, but also information on work-related diseases in developing countries is totally missing and lacking in developed countries. Nonetheless, there are some issues which affect the number of fatal work-related diseases. Attributable fractions are based on information on developed countries. While production processes are largely the same in all regions, some notable differences can be identified, in particular in estimating exposure levels: many production processes are considerably more labour intensive in developing countries than in industrialized countries; climatic conditions are usually more demanding in developing countries; knowledge and awareness of hazards and consequently prevention levels are significantly lower in low-income countries; less sophisticated machinery and equipment using lower energy levels are used in developing countries; there is more harmful exposure and without proper control measures; and communicable diseases at work are more prevalent. All these statements affect the estimated number, but could be taken into consideration only to a limited extent by revising some regions´ attributable fractions.

The remaining factors that limit generalization are meaningful, but not controllable by the author of this thesis. These factors decrease the external validity of the results, if they have not been considered first at the beginning of the research used in this study.

Overall, it is very hard to estimate reliably the number of occupational accidents and fatal work-related diseases. Occupational accidents are under-reported and work-related diseases go almost totally unreported in developing countries (Shahnavaz 1987). Especially in the case of developing countries, generalisations made might lead from totally wrong results. Epidemiological studies concerning work-related diseases are typically expensive, time-consuming and the results may not be generalised for the whole global population. Workplaces have different kinds of exposures and the combination of these is difficult to

study. Work-related disease often also depends on a person's own genetic background, exposure level and time and possibly other associated exposures or conducive factors. Globally, scientific studies are mainly conducted in developed countries and the information produced is also used for developing regions.

7. GENERAL CONCLUSION AND RECOMMENDATIONS

Estimates of occupational accidents and work-related diseases are not a new issue. Estimation is still done on a country basis, correcting insufficient recording both in developed and developing countries. In addition, the national recording system in many countries is insufficient, and the international collection of occupational accidents and especially work-related diseases is almost totally lacking. The International Labour Organization collects occupational injury data from its member countries, but information, especially from developing countries, is lacking. International records for work-related diseases cannot be found, and not even records for occupational diseases. The World Health Organization estimates the number of diseases worldwide, but it covers all diseases, not only work-related ones.

The main problems which we still face today are that coding methods are not standardised. The European Union has tried to harmonise its occupational accident and disease definition, but individual member countries have still their own coding systems and recording procedures, and that is why the data needs to be corrected. Countries' recording systems may vary even inside a country, e.g. the United States. In addition, there might be several bodies inside a country responsible for recording statistics. This furthermore affects the usability of available statistics.

In the present study the objective was to create models to estimate the global number of occupational accidents and fatal work-related diseases. The study problem arose from the need for valid and reliable occupational accident and work-related disease statistics. The growing interest in safety and health issues in a global perspective also affect the need for estimated figures. Inadequate statistics complicate safety and health work and give wrong information about the safety situation in a country.

The created models gave the result that approximately 2.2 million fatal occupational accidents and fatal work-related diseases occur annually. Every day circa 1,000 workers die because of an occupational accident and over 5,000 people die because of work-related disease. Every day over 900,000 workers will face an occupational accident. However these figures are still underestimations.

Even though the created models could produce estimates of occupational accidents and fatal work-related diseases, there is a need for a better and more accurate model. In the future, methods for estimating the number of occupational accidents and fatal work-related diseases will have to be corrected. The World Bank and the WHO divisions gave a good basis for

making estimates, but decreased the reliability of the results. Instead of using regional divisions each country should use its own information. Such information which is widely available and may affect the number of occupational accidents and work-related diseases are, e.g. the numbers of total employment, gross domestic product, urbanisation, and women in the labour force. Time series analyses based on the statistics of developed countries could be applied to developing countries.

In the case of fatal work-related diseases, the situation is more complicated than in the case of occupational accidents. The attributable fractions are based on epidemiological studies and are typically country or even industry based. In addition, epidemiological studies are usually concentrating on one factor and cannot deal with a combination of different diseases. On the other hand, occupational accidents have been investigated for a long time and the various factors contributing to them are well known. Also, even though studies have been mainly carried out in developed countries, the human metabolism and response is the same around the world. Recent studies show that there is pressure to correct epidemiological data which is old and does not fit with present knowledge (O'Neill et al. 2007; Rushton et al. 2007). Problems for the future, especially in the case of work-related diseases, are increasing. Understanding of how different hazardous substances and working conditions affect people is inadequate. The effects of current exposures need to be carefully considered, because the potential health effects may be important, but not evident for many years (Morrell et al. 1999; O'Neill et al. 2007). In addition, estimates for work-related diseases should also be obtained for cases other than fatal diseases. Especially muscular-skeletal disorders and neuro-psychiatric diseases are increasing problems in developed countries and the cause of most of the diseases in question. These diseases do not typically cause death.

When making comparisons between countries the standardised coding system and harmonisation of occupational accidents and work-related diseases statistics are required. Nishikitani and Yano (2008) suggested after studying differences in the lethality of occupational accidents in OECD countries that the waiting period for statistics or insurance could reduce differences in lethality. In the same way, the comparability of non-fatal occupational accidents and work-related diseases between countries would increase if the absence from work recorded is, for example, at least four days absence, which is used in EU countries. This would eliminate at least partly the differences in sick leave given by medical doctors because of accidents or work-related diseases. Of course, this does not eliminate the coding differences, but the variation in differences in minor occurrences will decrease. Regardless, at national level occupational accidents and work-related diseases should be recorded already after one day of absence for the purpose of national prevention.

Global occupational safety and health programmes should be focused on the developing countries and be supported by developed countries. Many enterprises in high-income countries are moving to work in low-income countries: multinational corporations might farm

out labour intensive and often more dangerous work to low-income countries where salaries are low and regulatory measures poor. Transfer of technology and industrial development without consideration for the characteristics of the local users and the environmental conditions of the developing recipient country is socially harmful and will cause human suffering and material losses (Shahnavaz 1987). Workers in developed and developing countries are entitled to the same human dignity and decent work conditions.

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APPENDIX 1: Examples of attributable fractions

Examples of attributable fractions used in some studies

	Attributable fraction											
	Nurminen and Karjalainen (2001)		Rushton et al. (2008)		Steenland et al. (2003)		Driscoll et al. (2005b,c)[a]		Morrel at al. (1998)[b]		Leigh at al. (1997)[c]	
Causes	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Communicable diseases	4.8	32.5										
Tuberculosis	0.6	75			5-6							
Malignant neoplasms	13.8	2.2	8.0	1.5	3.3-7.3	0.8-1.0						6-10
Bladder	14.2	0.7	11.6	2.0	7-19	3-19			10	5		
Kidney	4.7	0.8			0-2.3				1	0.5		
Larynx	9.3	0.5			1.0-20.0				2	1		
Leukemia	18.5	2.5	2.7	0.8	0.8-2.8		2 (b)	2 (b)	10	5		
Liver	3.5	5.3			0.4-1.1				4	1		
Lung	29.0	5.3	21.6	5.5	8.0-19.2	2	10 (b)	5 (b)	15	5		
Mesothelioma	90.0	25.0	98.0	90.0	85-90	23-90						
Non-melanoma skin cancer	13.1	3.8	11.8	3.0	1.2-6				10	2		
Sinonasal	24.0	6.7	64.3	18.4	33.0-46.0	30.0-42.0			25	5		
Respiratory diseases	6.8	1.1										10[c]
Asthma	17.8	18.4			11-12		21 (c)	13 (c)	2.0	2.0		
COPD	14.0	3.8			5-24		18 (c)	6 (c)				
Pneumoconioses	100	100			100	100			100	100		100
Circulatory diseases	14.4	6.7			6.3				1.0	1.0		5-10
Neuropsychiatric conditions	6.6	1.8							1.0	1.0		1-3
Digestive diseases	2.3	1.5										
Genitourinary system	3.0	0.4							1.0	1.0		1-3

[a] Attributable fractions have been taken from two separate papers of Driscoll et al.

[b] Cover only deaths due to occupational exposure to hazardous substances

[c] Pneumoconiosis are not included in the figure of Leigh at al.

COPD is chronic obstructive pulmonary diseases

APPENDIX 2: Original papers