Pia Perttula

Improving Occupational Safety in Logistics

– Accident Risks of Heavy Vehicle Drivers and Material Transfers at Construction Sites

Finnish Institute of Occupational Health

People and Work
Research Reports 95

People and Work

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Layout Mari Pakarinen / Juvenes Print
Cover Picture Mats Andersson, Kuvatoimisto Gorilla
ISBN 978-952-261-142-0 (paperback)
ISBN 978-952-261-143-7 (PDF)
ISSN-L 1237-6183
ISSN 1237-6183

Press Tampereen Yliopistopaino Oy – Juvenes Print, Tampere 2011

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Finnish Institute of Occupational Health
Helsinki, Finland

ACADEMIC DISSERTION

Thesis for the degree of Doctor of Science in Technology to be presented with due permission for public examination and criticism in Festia Small auditorium 1, at Tampere University of Technology, on the 16th of December 2011, at 12 noon.

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ABSTRACT

The importance of logistics is growing all the time, since materials are increasingly transported worldwide. Manufacturing is often done globally; while the different parts of products are produced in one country and the composition is performed in another, the final products are then transported worldwide. Competition and increased productivity are important issues in companies today.

An increase in the amount of materials being transported from one place to another also increases the risk of accidents. The objective of this study is to help recognise the factors that cause occupational accidents in logistics in order to improve occupational safety. As logistics is such a broad concept, after the examination of a logistic chain, this study is limited to two sectors: materials transported by trucks on roads, and materials transferred at construction sites.

The study is divided into three parts. The first part focuses on the issue of accidents during material transfers based on the national accident statistics in Finland. The perspective of the entire logistic chain is taken into account in order to discover the risk points for unwanted events. Two of the last sections of the study concentrate on more focused assessment phases of logistic chains. The second part of the study concentrates on the risk factors for road transport and the third part on improving occupational safety of material transfers related to accidents at construction sites.

The national accident statistics were analysed. A case-study concentrates on occupational accident risks and material damages in a logistic chain for paper transportation. A questionnaire was used to examine the breaks that professional drivers take and fatigue that they experience. Occupational accidents at a construction site were analysed and the influence of devices in material transfers were estimated in order to improve occupational safety and efficiency.

The number of occupational accidents that occur during the logistics phase is considerable; they account for one quarter of all fatal occupational accidents in Finland. The study at a construction site showed that the types of disabilities caused by material transfer-related accidents are more severe than the types of disabilities caused by other workplace accidents.

In order to increase productivity, more focus should be placed on widening accident prevention measures to cover entire logistic chains. It is not sufficient to address occupational safety at the level of isolated organizational units only. The functions and working methods of one particular phase in a logistic chain has great impact on subsequent phases. The risks in logistic chains, such as delays and material damages, may also lead to occupational accidents and, thus, unnecessary costs.

Fatigue is a widely known risk factor in traffic. However, heavy vehicle drivers occasionally work for longer amounts of time than is legal. This study showed that heavy vehicle drivers were less likely to fall asleep at the wheel if they could choose the time for their breaks.

The proper planning of material transfer is essential both on the roads and at construction sites. It is important to have appropriate devices for material transfers in order to avoid unnecessary lifting or carrying, which may result in back injuries.

This study shows that even though there are a lot of occupational accidents in material transfers, there are several things that can be done in order to prevent such accidents. The employer bears the main responsibility for preventing accidents in material transfers, but still there are several things that workers can do in order to improve their occupational safety. It is worthwhile that employers, the occupational health service and workers recognise the risks caused by material transfers so that they can co-operate in improving safer working conditions.

Keywords: occupational accident, accident prevention, professional driver

TIIVISTELMÄ

Logistiikan toimivuuden merkitys kasvaa koko ajan, koska tavaraa kuljetetaan ympäri maailmaa. Tuotteiden valmistaminen on nykyään globaalia toimintaa, sillä tuotteiden osia valmistetaan eri maissa, kokoonpano saatetaan tehdä toisaalla ja valmiita tuotteita kuljetetaan kaikkialle maailmassa. Nykypäivänä kilpailu ja tuottavuuden kasvu ovat yrityksille ratkaisevan tärkeitä.

Lisääntynyt tavarankuljetus lisää myös onnettomuuksien riskejä. Tämän tutkimuksen tavoitteena on parantaa työturvallisuutta materiaalinsiirroissa auttamalla tunnistamaan tapaturmien taustalla olevia tekijöitä. Koska logistiikka on laaja käsite, logistiikkaketjun tarkastelun jälkeen tarkastellaan vain kahta logistiikan osa-aluetta: raskaan liikenteen maantiekuljetuksia ja rakennustyömaan tavaransiirtoja.

Tutkimus on jaettu kolmeen eri osaan. Ensimmäisessä osassa keskitytään Suomessa sattuneisiin materiaalinsiirtotapaturmiin tilastojen valossa ja vahingontorjuntaan logistiikkaketjun riskikohtien näkökulmasta. Tutkimuksen kahdessa jälkimmäisessä osassa logistiikkaketju on pilkottu pienempiin osiin siten, että tutkimuksen toinen osa keskittyy maantiekuljetusten työtapaturmariskeihin ja kolmas osio materiaalinsiirtoihin liittyvään tapaturmantorjuntaan rakennustyömaalla.

Tutkimuksessa on analysoitu työtapaturmatilastoja. Tapaustutkimuksessa tarkasteltiin paperinkuljetusketjua ja siihen liittyviä tapaturmariskejä sekä materiaalivaurioita. Ammattikuljettajien taukojen viettämistä ja työaikaista väsymystä arvioitiin kyselytutkimuksen avulla. Rakennustyömaan tapaturmia tutkittiin analysoimalla sattuneita työtapaturmia ja arvioitiin apuvälineiden vaikutusta työturvallisuuden ja tehokkuuden parantamiseen materiaalinsiirroissa.

Tavaransiirroissa sattuu paljon työtapaturmia. Suomessa materiaalinsiirrot aiheuttavat neljäsosan kuolemaan johtaneista työtapaturmista. Rakennustyömaalla tehty tutkimus osoitti, että materiaalinsiirtoihin liittyneet työtapaturmat olivat vakavampia kuin muut rakennustyömaalla sattuneet tapaturmat.

Koko logistiikkaketju kannattaa ottaa huomioon silloin kun tavoitellaan ketjun tuottavuuden lisäämistä. Työturvallisuuden edistämisessä keskitytään yleensä vain yhden työpaikan tai osaston turvallisuuden kehittämiseen ja tapaturmien tutkimiseen. Logistiikkaketjuissa tulisi huomioida myös edeltävät ja seuraavat vaiheet, sillä tapahtumat ketjun alkupäässä vaikuttavat ketjun myöhempiin vaiheisiin. Logistiikkaketjun riskit, kuten viivästykset ja materiaalivauriot, saattavat johtaa tapaturmiin ja sitä kautta myös ylimääräisiin kustannuksiin.

Liikenteessä väsymys on tunnettu riskitekijä. Siitä huolimatta raskaan liikenteen kuljettajien työajat ylittävät välillä lain sallimat rajat. Tässä tutkimuksessa tuli ilmi, että mikäli kuljettajat saivat valita taukojensa ajankohdan, niin heidän riskinsä nukahtaa ajon aikana pieneni.

Suunnittelu on tärkeää materiaalinsiirroissa sekä maantiellä että rakennustyömaalla. Asianmukaisten apuvälineiden ja laitteiden käyttäminen materiaalinsiirroissa vähentää tarpeetonta selkää rasittavaa taakkojen nostamista ja kantamista.

Tämä tutkimus osoittaa, että vaikka materiaalinsiirtoihin liittyviä työtapaturmia sattuu paljon, niitä on mahdollista ehkäistä. Materiaalinsiirtoihin liittyvien tapaturmien ehkäisyssä päävastuu on työnantajalla, mutta myös työntekijät voivat itse vaikuttaa omaan työturvallisuuteensa. Sekä työnantajan, työterveyshuollon että työntekijöiden on hyödyllistä tunnistaa materiaalinsiirtoihin liittyvät riskit, jotta eri osapuolet voivat yhteistyössä kehittää työskentelyolosuhteita turvallisemmiksi.

Asiasanat: työtapaturma, tapaturmantorjunta, ammattikuljettaja

PREFACE

My interest in improving occupational safety provided me with the initial motivation to write this doctoral thesis. In addition to my interest in such an important subject, this thesis also shows my commitment and perseverance to finishing what I once started. Although the whole process took quite a long time, it was also very educational. Not only did I learn about scientific theories, but I also learned how lucky I am to have so many helpful and encouraging people around me.

The funding for this doctoral thesis was provided by the Academy of Finland and the Finnish Work Environment Fund. I am grateful to these organisations for their support. I also want to thank the Finnish Institute of Occupational Health for providing me the opportunity to complete my doctoral thesis. I am also grateful to all the co-authors of the original papers for their strong co-operation.

I want to thank Professor Kaija Leena Saarela for her straightforward and positive guidance during the project. I also want to thank Professor Veikko Rouhiainen and senior specialist Seppo Olkkonen for examining this thesis and ensuring that the demands of the doctoral thesis are fulfilled. I would also like to express my gratitude to those involved in the publishing of my doctoral thesis.

I am grateful to my work community for all the support I received during the process. I want to thank my workmates for being interested and encouraging during the whole process. In particular, I want to thank Professor Jorma Saari for his guidance and support. Docent Simo Salminen was my mentor and offered valuable support during the process. I also want to thank my supervisor, Dr Markku Aaltonen, for being so flexible and encouraging.

I want to thank my husband Petri for his support and for being the one that I have been able to count on. I also thank him for actively ensuring

that during the project I every now and then have been able to relax in the sunshine that I love. I also want to thank my daughters Paula and Ella for bringing a ray of sunshine and joy to every day.

LIST OF ORIGINAL PAPERS

The doctoral thesis is based on six original papers (Table 1), which are referred to in the text by their Roman numerals. Beneath the citation for each original paper, I mention my contribution to the paper.

Table 1. List of original papers

Number	Original paper
I	Perttula, P. & Salminen, S. 2011. Workplace accidents in materials transfer in Finland. Journal of Occupational Safety and Ergonomics. (accepted for publication) Perttula studied the data used in the paper and provided the analysis in co-operation with the other author. She wrote the paper in co-operation with the other author.
II	Perttula, P. 2010. Safety of a Logistics Chain – a Case Study. Logistics Research (2), pp. 159–163. Perttula worked as a researcher on the case study, "The safety of logistic chains".
III	Salminen S., Perttula P. & Merjama J. 2005. Use of rest breaks and accidents by professional drivers. Perceptual and Motor Skills 101, pp. 665–668. Perttula worked as a researcher in the study. She did all the statistical tests for the paper and made the comments and corrections to the text produced by the 1st author.
IV	Perttula, P., Ojala, T. & Kuosma, E. 2011. Factors in the fatigue of heavy vehicle drivers. Psychological Reports, 108 (2), pp. 1–8. Perttula worked as a researcher in the study. Perttula participated in analysing the results using SPSS-program and was primarily responsible for producing the paper.
V	Perttula, P., Kiurula, M., Merjama, J. & Laitinen, H. 2003. Accidents in materials handling at construction sites. Construction Management and Economics, Vol. 21 (7), pp. 729–736. Perttula worked as a researcher in the study. She chose all the data to be examined and encoded the data and analysed it with the help of the other authors. She wrote the text for the paper and the other authors added their comments to it.
VI	Perttula, P., Korhonen, P., Lehtelä, J., Rasa, P-L., Kitinoja, J-P., Mäkimattila, S. & Leskinen, T. 2006. Improving the Safety and Efficiency of Materials Transfer at a Construction Site by Using an Elevator. Journal of Construction Engineering and Management 132 (8), pp. 836–843. Perttula worked as a researcher in the study. She wrote the introduction and the materials and methods text and contributed to the discussion chapter. She coordinated the writing of the paper.

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KEY DEFINITIONS

Accident	Undesired event giving rise to death, ill health, injury (BS 8800 2004).
Fatal accident	An accident that leads to the death of a person suffering from an injury (Studenski et al. 2010).
Logistics	Flow of materials and information. The focus of this study is on the flow of materials.
Logistic chain	The supply chain of a material beginning from the time it is stored at a plant and ending at the time it is delivered to the client.
Materials handling	Materials handling is the lifting, moving and placing of items in various forms (Brauer 2006, p. 237).
Manual materials handling	Manual handling includes all lifting, carrying, supporting, putting down, and pulling or pushing with bodily force, i.e. using hands, shoulders, back or any other part of the body. (Davies et al. 2003). See also: Material transfers.
Material transfers	Material transfers may be manual or mechanical. In most of the references used in this study, the term "Materials handling" is used. This study uses the term material transfers to describe the process of transferring material from one place to another.
Mechanical materials handling	Material transfer which is performed with a mechanical device. See also: Material transfers.
Occupational accident	Accident which occurred while working or commuting between home and workplace.
Risk	Combination of the frequency, probability or occurrence and the consequence of a specified hazardous event (Harms-Ringdahl 2004).
Supply chain	A network of multiple businesses and relationships (Lambert & Cooper 2000).
Road accident	An accident where a road vehicle drives off the road or collides with another vehicle or people and leads to injury or material damage.
Workplace accident	Occupational accident which occurs while working, i.e. excluding commuting between home and the workplace.

1 INTRODUCTION

Logistics is an everyday operation in most branches of business, since technology has developed and products are transferred worldwide. Logistics is very often examined on the basis of efficiency (Hameri & Lehtonen 2001; Jeschonowski et al. 2009; Koskinen 2009). This study focuses on occupational safety in logistic operations. Increasing occupational safety usually increases efficiency and productivity (Brauer 2006).

Material transfers often cause back injuries when performed manually (Troup et al. 1988) and lead to accidents when performed mechanically (Brauer 2006). An interesting question is whether the factors underlying the accidents are the same in manual and mechanical transfers. When considering preventive methods, it helps to recognise the factors underlying the accidents.

The way in which materials are transported to construction sites has changed significantly in the past century. Previously, buildings were made of the materials available in a particular area. After transportation vehicles became more common, the materials could more easily be transported across greater distances, and today construction materials are transported worldwide. The significant changes in the transportation of materials to construction sites supports the objective of this study to use construction sites as an example of material transfers at a workplace. Most construction materials are transported by trucks to the construction sites. The downside is that the increase in the amount of transportation has increased the number of accidents. For this reason, the study also focuses on road safety as an aspect of transportation. In doing so, it concentrates primarily on the driver, while excluding the mechanical features of the vehicles. Thus, the study examines both the outside and inside logistics of a company (Figure 1). Although every workplace has its own special

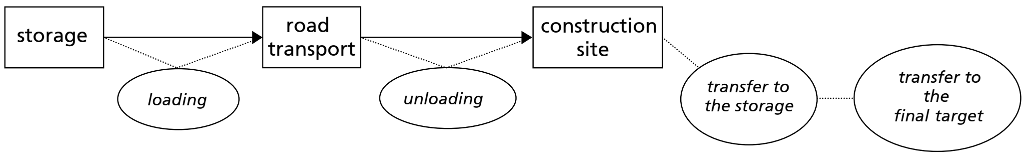

Figure 1. Material transfers in this study

features, most preventive actions against occupational accidents can be utilised in any workplace.

Logistics is a broad concept. The study provides an overview of occupational accidents in logistics in Finland and identifies factors which have a great influence on such accidents. In terms of global transportation, the study uses a logistic chain as part of an example of the transport of paper reels between two countries. Since logistics is such a broad concept, the study focuses on two different aspects of logistics: 1) materials transport by trucks along roads, and 2) material transfers at a construction site.

The need to improve logistics is growing all the time. Companies are using subcontractors worldwide and even the smallest parts are transferred from one place to another for production. The European Commission recognises the importance of safety to transportation and has stated that a central objective of transport research is to develop safer transport systems and increase the comparative advantage of European industries in the global market (Eurostat 2009).

Many products require unique means of transportation. The means of improving occupational safety are mostly the same, regardless of the product. The means of preventing occupational accidents during the logistics phase can be used in almost any branch of business. The aim of this study is to help recognising the factors that cause occupational accidents during the logistics phase. Recognising the causal factors helps in preventing such accidents.

Workplaces need to improve their inner logistics. Workplaces face problems pertaining to transportation safety and, although every workplace is different, the safety problems are often the same. By improving the safety of material transfers in the workplace, efficiency will also be improved.

The thesis provides different points of view on the occupational safety of material transfers:

- the extent of the occupational accidents in logistics *(I, V)*
- managerial perspective *(II, III, IV, VI)*
- workplace perspective *(IV, V, VI)*
- individual perspective *(IV, V, VI).*

All of these points of view are important in order to improve occupational safety. The best results are obtained when all of these aspects are taken into account. Working to improve occupational safety is a continuous process that is never finished. New challenges occur all the time in a continuously changing environment and working life. When taking into account the entire logistic chain, it should be noticed that a minor mistake at the early phase of the chain may result in a serious accident at the other end of the chain.

2 THEORETICAL BACKGROUND

2.1 Improving occupational safety

Occupational safety is based on accident prevention. All working people have a stake in it (Barling & Frone 2004). There are several recognised ways to improve occupational safety: education and training, safety campaigns, the management's commitment to safety, and so forth. The methods for improving occupational safety support one another and they work better when used side by side. Any accident is a signal to management that something has gone wrong (Petersen & Goodale 1980).

Top management is in a key position to improve occupational safety because preventing accidents and creating a better safety culture requires resources. According to Barling and Frone (2004), those leaders who value safety highly also value their employees' well-being. The well-being of the employees is essential when a company decides to devote itself to occupational safety.

The term safety culture describes how safety practices are actually carried out in a workplace. The roots of occupational accidents may be found in the safety culture of a particular company (Whittingham 2008). A good safety culture has a positive influence on the quality, reliability, competence and productivity of a company (Cooper 1998). The safety culture of a company can be directed but it cannot be forced. Management's role in creating a good safety culture is important (Redmill & Rajan 1997).

Leaders can increase the commitment of workers to safety by showing that they do not accept unsafe behaviour. Leaders should also clearly show in their own behaviour the importance of occupational safety (Barling & Frone 2004). Good safety practices at a workplace may extent outside the workplace as well. As an example, Wills et al. (2009) state that when a workplace has a good safety culture, it can also be seen in traffic as safe driving.

When talking about safety, the idea is to prevent accidents and not only to survive them. Accident prevention has traditionally been taken into account after an accident has happened. A motivation to prevent similar accidents arises after the total loss has occurred and resulted in significant economical costs. Doing things safely should be a part of operational practices both at the individual and at the organizational level (Hollnagel et al. 2006).

After years of this sort of reactive way of preventing accidents, the way of thinking is now more proactive (Hollnagel et al. 2006). Today, the topic is resilience when considering safety at workplaces. It is possible that things could go wrong even though everything possible is taken into account. Resilience refers to the ability to face unpredictable challenges and to flexibility act in such a way that operations can return to the normal with only minimum damage (Hollnagel et al. 2008). Resilience thinking should be taken into account at construction sites in particular, since the time of deliveries varies and different operators are dependent on delivery times. There are also workers from different companies at construction sites, so it is also essential to take into account the perspective of a joint workplace when talking about improving occupational safety at a construction site.

2.1.1 Human aspect

The importance of occupational safety is undeniable. The victims of occupational accidents are persons who also have commitments outside the workplace. Accident prevention is a vital factor in every workplace in order to avoid needless human suffering (Heinrich et al. 1980).

Legislation sets requirements for safe work. Legally, the employer is ultimately responsible for occupational safety (Petersen & Goodale 1980; Occupational Safety and Health Act 738/2002). However, employees can also influence the safety of their workplace by informing employers about unsafe spaces and activities at the workplace and by suggesting safety improvements. In addition to continuous monitoring workplace safety, the employer must take corrective actions after receiving a message about unsafe working conditions (Occupational Safety and Health Act 738/2002).

According to Brauer (2006), safety is nothing more than a lot of common sense, but the problem is that human capabilities for achieving safe behaviour are not universal. Individuals have different levels of training, experience, knowledge and skills different abilities in terms of recognizing hazards, perceiving dangerous situations in a timely manner, making sound judgments and taking the correct protective action (Brauer 2006). The safety culture of a workplace plays a vital role in workers' safety behaviour. Even if an individual understands the risks, pressure from the work team may cause him/her to take unsafe actions (Hillson & Murray-Webster 2007).

People generally feel that safety is important (Brauer 2006), but still they take unsafe actions which may lead to an accident (Mullen 2004). In cases when they consider the risks to be small, people may take unsafe acts in order to save time (Hale 2003). Everyone can participate in accident prevention. Each worker has ideas about the causes of accidents and methods for preventing them (Kouebenan 2009). Workers' participation in creating a safe workplace is crucial. However, the employer has the possibility and responsibility to require safe working methods and to ensure the resources for working safely. Requirements and procedures should be clearly explained and workers should be motivated to follow the safety requirements. People tend to ignore information that is inconsistent with their beliefs and wishes (Pate-Cornell & Murphy 1996).

People usually have a reason for why they act in a particular manner. After an accident has occurred, it is easier to see what actions were related to the cause of the accident. But, at the moment of an accident, the outcome is not yet known and, thus, the way a worker acts may seem rational to him/her at the time (Woods et al. 2010). Learning from accidents and near-miss situations helps people to react in similar situation later. At the point of an uncertain situation, for example a situation with a huge risk, people tend to find a solution based on prior experiences (Hillson & Murray-Webster 2007).

2.1.2 Occupational accidents

Occupational accidents can be seen as a result of unsuccessful interactions between workers, the equipment and the environment (Andersson & Menckel 1995). The number of occupational accidents worldwide is not exactly known because the statistics are compiled differently (Barling & Frone 2004). Still, in terms of occupational accidents worldwide, it has been estimated that there were 264 million non-fatal accidents and 350 000 fatal accidents in 1998 (Hämäläinen et al. 2006). Globally, the number of fatal occupational accidents has increased between 1998 and 2003 (Hämäläinen 2010). According to European Union data, each year 4 out of 1000 employees die because of accidents at work (Studenski et al. 2010). In Finland there are approximately 130 000 occupational accidents yearly and about 40 employees die at work every year (FAII 2010a).

The number of risk factors that influence accidents is vast (Elvik 2006). The causes of occupational accidents are not unambiguous. According to Cooper (1998), most occupational accidents are due to unsafe behaviour. It is estimated that 80–90% of accidents are caused by human error (Heinrich et al. 1980). Reason (1997) claims that even though human error is often listed as the cause of accidents, human errors are in fact consequences rather than causes. Human error can be managed up until a certain point, but it can never be totally eliminated (Reason 1997). Opinions are divided as to whether risk-taking by workers is related to occupational accidents or not (Salminen et al. 1999).

The idea of a blunt end and a sharp end in a complex system shows that the procedures and resources are usually generated by persons other than those who performed the actual operations. Sharp-end practitioners are those who work directly on the tasks where a risk of an injury exists, whereas blunt-end practitioners provide them with the resources they need for the operation. Organizational factors at the blunt end create the resources for practitioners at the sharp end. The goals generated by blunt-end operators are sometimes conflicting. In addition to written policies and procedures, there may be implicit and unstated goals. (Woods et al. 2010)

2.1.3 Economical benefits of preventing occupational accidents

The economic aspects of operations are important in today's working life. Most of the operations performed in workplaces are considered on the basis of their economic value. Accidents cause extra costs for companies and also for society (Hopkins 1999), and they entail costs and have a negative effect on the health of workers, the enterprise and the atmosphere of the workplace (Miller & Galbraith 1995). To prevent these costs, the emphasis should be on preventing accidents (Lanoie & Tavenas 1996).

The exact amount of costs caused by occupational accidents is not known (Barling & Frone 2004). It is quite difficult to calculate the indirect costs of an occupational accident, even though some methods do exist (Jallon et al. 2011). Beevis & Slade (2003) state that the costs and benefits resulting from better ergonomic practices are not reliably known. Thus, it is not known how much money is saved because of accident prevention or improved ergonomics. Anyway, it is clear that safety and productivity are interconnected (Brauer 2006). It has been estimated that injury costs in the construction industry account for 15% of the injury costs of all industries in the U.S. (Waehrer et al. 2007). In a Finnish case-study of 23 workplaces representing different branches of business, it has been estimated that one occupational accident costs 6000 € (Aaltonen et al. 2007).

A logistic chain is usually examined on the basis of its productivity and efficiency (Hameri & Lehtonen 2001; Xiao & Yang 2009; Jeschonowski et al. 2009; Koskinen 2009) and synchronization (Puikko 2010). Recently, the emphasis has also been on environmental and ethical issues (Closs et al. 2011). The risks in supply chains are often seen as business risks (Bogataj & Bogataj 2007; Lai et al. 2009; Xia & Chen 2011). The main concern is usually whether the products are transported as scheduled, and whether the capacity of the transport equipment is fully utilized. The improvements in supply chains may have more to do with reducing lead times (de Treville et al. 2004). Since productivity and efficiency are related to safety, an interesting point of view also has to do with accident prevention in the entire supply chain. It may be easier to consider material damages in the entire logistic chain because the damages affect the next phase of the supply chain. The concern should not only pertain to material damages; as according to Hoyos & Zimolong (1988), the same factors can lead to either damages or/and injuries.

2.2 Material transfers and transportation

In Europe, road transport accounted for the largest share (46%) of total goods transportation in 2009. In the EU, the number of vehicles that transport goods has increased at an average yearly rate of 3.1% from 1990 to 2006. Road transport accounted for 1900 billion ton-kilometres in the EU in 2007. (Eurostat 2009)

Road transport by trucks accounted for 25.2 billion ton-kilometres in Finland in 2009 and road traffic accounted for 68% of domestic transport. Heavy vehicle traffic on the highways decreased in 2009 because of an economic recession, but it increased again towards the end of the year. The number of heavy vehicles has almost doubled within the last ten years, since in 1999 the number of lorries was 61 027 and in 2009 the number was 111 267. (Finnish Transport Agency 2010). The number of vehicles on Finnish roads has since increased; in addition to the increase in number of lorries, the amount of passenger cars has increased at an average yearly rate of 1.6% between 1990 and 2006 (Eurostat 2009), which means an overall increase of 29.2% (Finnish Transport Agency 2011).

The number of road fatalities decreased by 3.5% between 1990 and 2006, but still there were 1.3 million road accidents in the EU in 2006 and 42 950 people died as a result of these accidents. Heavy vehicles were involved in 3% of the road fatalities in 2006 (Eurostat 2009). The number of fatal traffic accidents in Finland was 255 in 2009 (Statistics Finland 2011) and 279 people died as a result of these accidents (Finnish Transport Agency 2010). A heavy vehicle was involved in a collision in 49 cases in Finland in 2009, which means that a heavy vehicle was involved in every fifth fatal road accident (Finnish Motor Insurer's Centre 2010).

Material transfers are carried out in almost all workplaces in some form, either manually or mechanically. The need to improve logistics is growing all the time. Companies are using subcontractors worldwide and the number and volume of parts and materials that are transported from one place in the world to another for production is continually increasing. It is common in material transfers and transportation that the flow of goods is somehow unpredictable (Ingelgård et al. 1996). In a changing world, it is inevitable that companies rely heavily upon suppliers and alliances and individual businesses no longer compete alone but rather as a part of supply chains (Christopher & Towill 2000). Unwanted events in material transfers cause transportation delays.

Within one workplace, there may be employees from several different companies. This makes the management of logistical activities even more complex. The mission of logistics management is to achieve the desired levels of customer service and quality at the lowest possible cost (Tanskanen & Hameri 1999). Within the context of supply chain management, it has mostly been the cost, time, quality and service that has been discussed (Winkler 2009). Within the manufacturing environment, improving material transfers includes performance, reliability and performability (Beamon 1998). However, the human factor has been seen as a flexible component and as a key contributor to the success of companies in different markets (Kara & Kayis 2004). According to the existing literature, safety at the supply chain level is not widely studied. One recent study examined food safety at the supply chain level (Bosona & Gebresenbet 2011). Another study from South Africa examined underground logistics from a safety perspective and found that 26% of all mine accidents are due to problems with transportation (Rupprecht 2011).

Activities at work should be performed in a safe manner and also by following the rules of ergonomics, which helps to prevent musculoskeletal disorders (Roman-Liu 2010). Material transfers can be facilitated when companies provide transfer devices such as forklifts, trucks and push carts and an appropriate layout design (Kara et al. 2002). Utilising transfer devices is important in preventing over-exertion. Pulling and pushing and lifting and carrying put the greatest strain on the musculoskeletal system (Roman-Liu 2010). The risks involved in material transfers depend also on factors other than manual transfers. In a Canadian study of warehouse workers, the risks to workers depended on the way the goods were stored; a wide variety of products and the difficulties involved in handling them also caused difficulties for the workers (St-Vincent et al. 2005).

2.2.1 Manual material transfers

Manual material transfer is a common cause of workplace injuries (Ridley 2003; Davies et al. 2003). Manual material transfer injuries are linked to how the materials are handled, to job design and to the physical condition and characteristics of individual workers (Brauer 2006). Manual material transfer is a hazardous activity, especially for the lower back (Troup et al. 1988; Gagnon 2003; Dempsey & Mathiassen 2006). Risk factors involved in manual material transfers include the characteristics of the load, physical effort, the working environment and the requirements of the handling activity (Table 2). Working with loads which require that both hands are above shoulder height may cause a loss of balance (Denis et al. 2006).

Manual material transfer increases the risk of falling. In a U.S. transportation company, 40% of the material transfer-related accidents occurred when the handler did not have both feet on the ground (Lortie & Pelletier 1996). Risks for manual material transfer accidents may also involve the characteristics of the equipment, workplace layouts and work organization (St-Vincent et al. 2005). These risks could be decreased by ergonomic considerations. Manual transfer aids used for assisting in lifting or decreasing the need for carrying loads also have to be considered on the basis of ergonomics (Mack et al. 1995). However, a U.S. assessment of manual material transfer showed that many basic ergonomic considerations were ignored (Ciriello et al. 1999).

Materials that need to be transferred should be placed in such a way that they are safe to transfer. Here, the role of the supplier comes into play, since the way in which materials are packed influences the handling of the materials, that is to say, the heaviest materials should be packed at the lowest level so that the piles remain stable and the next handler need not carry the materials above shoulder level. Haslam et al. (2005) found that suppliers do not always pay attention to the manual handling of materials and that this causes risks, especially with heavy materials.

Because of the number of accidents associated with manual material transfers, many organisations are concerned with ensuring that the amount of manual handling required of employees is significantly reduced. The introduction of mechanical lifting devices and the provision of manual handling training are obvious strategies for assisting in this area. Nonetheless, assessing people's perceptions with respect to the types of manual handling issues thought to be important to employees can be of enormous value (Cooper 1998). The technique of material transfers differs depends on the work experience of the employees (Authier et al. 1996).

Table 2. Risk factors involved in manual material transfers (EUR-Lex 1990)

Characteristics of the load	Weight and shape (too heavy or too large, unwieldy or difficult to grasp) Stability (unstable or has contents likely to shift, positioned in a manner requiring it to be held or manipulated at a distance from the trunk of the body, or with a bending or twisting of the trunk)
Physical effort required	Too strenuous Only achieved by a twisting movement of the trunk Likely to result in a sudden movement of the load Unstable posture
Working environment	Tightness (there is not enough room, in particular vertically, to carry out the activity) Surface of the ground (the floor is uneven, thus presenting tripping hazards, or is slippery in relation to the worker's footwear, the floor or foot rest is unstable) Working height (the place of work or the working environment prevents the handling of loads at a safe height or with good posture by the worker) Various levels (there are variations in the level of the floor or the working surface, requiring the load to be manipulated on different levels) Work hygiene (the temperature, humidity or ventilation is unsuitable)
Requirements of the activity	Over-frequent or over-prolonged physical effort involving in particular the spine An insufficient bodily rest or recovery period Excessive lifting, lowering or carrying distances A rate of work imposed by a process which cannot be altered by the worker

In Australia, manual material transfer is the most common cause of occupational injuries resulting in at least one week's disability (Friswell & Williamson 2010). In a study of Liverpool hospital patients, Davies et al. (2003) found that one in every five injuries caused by manual transfer required more than a month's absence from work.

2.2.2 Mechanical material transfers

Mechanical material transfers include transfer work which is performed with mechanical help (that is to say, by truck, van, hoist, and so forth). Mechanical material transfers also include some outside transfer work phases that are essential while performing transfers. Mechanical devices can reduce the risk of over-exertion (Gallagher 2005). Mechanical handling aids in reducing the force required to move a heavy load (Holt 2001). A study of Canadian warehouse workers showed that replacing a mechanical gathering process with a manual gathering process reduced accidents and worker boredom (Lanoie & Trottier 1998). On the other hand, the same study demonstrated that using an automatic pallet distributor decreased both the ergonomic problems of workers and material damages in terms of the increased use of those pallets (Lanoie & Tavenas 1996; Lanoie & Trottier 1998). A Canadian study of nurses showed that using mechanical lifting devices decreases the risk of lower back injuries, but the frequency of the physical load ultimately influences the true risk of injury to the lower back (Santaguida et al. 2005).

Mechanical material transfers also include risks. Mechanical material transfer vehicles may have visibility problems and there are also risks of hazards related to traffic and the movement of several vehicles in the same area (Brauer 2006). In addition, manual material transfers cause lower back problems; then again, mechanical material transfers do as well. This was found out, for example, in a U.S. study of package truck drivers, which showed that 73% (n=317) of the drivers reported experiencing back pain and psychological stress related to their work environment (Orris et al. 1997).

2.2.3 Legislation concerning material transfers

Legislation exists to protect employees' safety and general health (Magowan 1999). In Finland, the Occupational Safety and Health Act (Occupational Safety and Health Act 738/2002) aims to reduce the risk of diseases and injuries at work. The directive (90/269/EEC) aims to reduce the risk of musculoskeletal diseases in manual material transfers. The directive states: "*Where the need for the manual handling of loads by workers cannot be avoided, the employer shall take the appropriate organi-*

zational measures, use the appropriate means or provide workers with such means in order to reduce the risk involved in the manual handling of such loads" (EU-Lex 1990).

Social legislation pertaining to road transport requires that heavy vehicle drivers take breaks during their work shifts (Road Traffic Act 267/1981). Regulations concerning drivers' working hours and periods of rest are uniform throughout the European Union and the European Economic Area. They are defined by Council Regulation (EEC) No. 3820/85, which came into effect on 20.12.1985. The regulations limit the amount of time drivers are allowed to work during a 24 hour period to a maximum of 9 hours per day, with the possibility of working 10 hours per day two days a week. After six consecutive working days, the legislation mandates that drivers take a weekly rest period consisting of at least 45 consecutive hours of free time. Furthermore, drivers' working hours are regulated by a collective agreements signed by employers' organizations and trade unions as well as by the Working Hours Act (605/1996). (Accident Investigation Board of Finland 2004)

2.3 Occupational accidents in material transfers

Material transfer-related accidents are considerable, both in terms of their overall numbers and in lost working days. According to the U.S. National Safety council, 20–25% of all disabling occupational injuries are caused by material handling (Brauer 2006). Injuries among transport and retail workers are considered to be more serious than other accidents (Santana et al. 2009). A Spanish study found that transport and elevation devices are involved significantly more often in fatal occupational accidents than in non-fatal accidents (Villanueva & Garcia 2011).

A Danish study demonstrated that accident risks at work for 17–18 year-old workers occurred most often as a result of lifting heavy objects and a lack of support from management (Rasmussen et al. 2011). One reason for young people suffering from lower back pain is that, due to their lower seniority, they are placed in jobs that require more manual material handling (European Agency for Safety and Health at Work 2010). Construction work is a typical example of work that includes a lot of manual material transfers.

According to the Finnish national occupational accident statistics database (FAII 2010b), 541 813 occupational accidents occurred between 2005 and 2008. The proportion of workplace accidents was 86% and the rest occurred while commuting. Carrying materials by hand as a specific physical activity accounted for 16% of the accident cases. The number of workplace fatalities was 116 between 2005 and 2008, five of which occurred while carrying materials by hand.

The amount and severity of the accidents depends in part on the transfer system. A Canadian intervention study at a warehouse where an automatic pallet distributor was introduced showed that the distributor decreased the need for the workers to take heavy wooden materials from the top of a high stack and place them on their pallet truck. The intervention study showed that the passage from a mechanical to a manual transfer system reduced workplace accidents among workers (Lanoie & Trottier 1998). Because of high load volumes and the heavy weights of the transfer equipment, the consequences are likely to be more serious when an accident does occur. A study of the trucking industry in the U.S. found that the number of motor vehicle accidents accounted for only a minority of the 3053 accident cases that were studied, but that their severity was much higher (Lin & Cohen 1997).

2.3.1 Accidents and risk factors for heavy vehicle drivers

Occupational accidents in road transport may result in serious consequences because of the large volumes and weight of the vehicles and loads. An Australian study found this to be the case: it showed that transport and storage workers had the highest rate of work-related road deaths between the years 1989 and 1992 (Mitchell et al. 2004). The accident risks for road transport may be a result of actions taken by the drivers and as well from other factors, like the traffic environment or other vehicles. Factors not related to driver include weather (Brijs et al. 2008), road conditions (Ushman et al. 2010) and other road users (Stanton & Salmon 2009). It is preferable not to drive in bad weather; a U.S. study showed that half of all drivers limit the amount of driving they do during bad weather (Naumann et al. 2011). However, heavy vehicle drivers usually cannot choose whether or not to drive in bad weather because their schedules are determined by the employer and customer.

No one wants accidents to occur. Accidents in road transport put drivers, passengers and the other people involved in the accident at serious risk. If the material that is transported includes hazardous substances, accidents may also cause water, air and soil to become polluted (Oggero et al. 2006). In the United States, motor vehicle accidents are the leading cause of both fatal and non-fatal occupational accidents (Brauer 2006). Road traffic accidents constituted 9.6% of all work-related accidents in 2007 in Europe (European Commission 2010).

For safe driving, it is essential for drivers to adjust their speed to match that of the surrounding traffic. At any rate, it may be difficult for drivers to estimate the distance and speed of vehicles in front of them (Hoyos & Zimolong 1988). Accidents can be seen as a result of driver errors. Factors that lead to driver errors include:

- road infrastructure (i.e. layout, maintenance, regulation)
- vehicle (mechanical, human-machine interface)
- driver (physiological and mental state, training, experience)
- other road users (behaviour, law enforcement)
- environmental conditions (weather, lighting, time of day) (Stanton & Salmon 2009).

Factors such as age and speed have been studied as possible risk factors when driving in traffic. A literature review showed that drivers younger than 27 years of age as well as drivers aged 63–68 are at an increased risk of being involved in a crash (Duke et al. 2010). High speeds increase the risk of crashes (Mitchell et al. 2004) and serious or fatal traffic accidents (Ayuso et al. 2010). Drivers who speed are more likely to commit other violations, too. According to a Finnish study, drivers who reported more errors were also more guilty of being involved in crashes, whereas those drivers who were fined for violations did not report errors (Mesken et al. 2002). This means that those drivers who are punished for speeding tend to shift the blame onto other parties.

Risk factors for work-related driving include haste, thinking about work, using mobile phone while driving and being overly tired (Salminen & Lähdeniemi 2002). The risk of being in an accident increases when the driver has to perform several cognitive tasks (i.e. talking to passengers, listening to the radio or having a conversation on the mobile phone) while driving (Elvik 2006). A Norwegian study showed that an increased risk of being in an accident exists when drivers use any kind of mobile phones while driving (Backer-Gröndahl & Sager 2010).

Lack of sleep is a significant indicator of accidents, driver fatigue and fatigue-related crashes (Arnold et al. 1997; Bunn et al. 2005; van den Berg & Landström 2006; Gander 2006). It is generally known that fatigue is a risk factor both while driving in traffic (Horne & Reyner 1999; Sagberg 1999; Lin & Cohen 1997) and while at the workplace (Häkkänen & Summala 2000). Sleep deprivation can be considered one of the causes of fatigue. Sleep debt increases the risk of accidents at work and while in traffic (Carter et al. 2003). Fatigue significantly increases reaction times and degrades driving performance (Philip et al. 2003). The major causes of fatigue include:

- the time of day of the transport operation
- a long duration of wakefulness
- inadequate sleep
- pathological sleepiness
- prolonged work hours (Åkerstedt 2000).

An interesting question is why drivers continue driving when fatigued, even though it is known that it includes risks. It is possible that drivers see the risks as being acceptable because of the benefits gained when accepting the risk of fatigue (Whittingham 2008). Accepting the risk of fatigue may mean getting home sooner as a result of not taking breaks. A U.S study stated that one reason why drivers continue driving when they feel fatigued has to do with a lack of secure rest areas (Roetting et al. 2003). Another explanation for driving when feeling fatigued is that drivers may underestimate the likelihood that they will fall asleep (Reyner & Horne 1998). Fatigue causes reduced concentration, poor decision making and, probably, compromised safety (Haslam et al. 2005).

A survey of 640 commercial goods drivers operating across 17 countries showed that fatigue problems were related to an early start time for the work shift. Fatigue problems also occurred when management did not support taking periodic breaks during the work shift (Adams-Guppy & Guppy 2003).

Since young drivers are involved in traffic accidents more often, one might expect that more driving experience decreases the risk of accidents. This may be true for professional drivers because they probably invest in safe cars and it is more likely that they drive on safer roads, like motorways. On the other hand, those drivers who drive long distances may adopt smaller margins for error because they believe that their greater experience allows them to do so (Elvik 2006). Also, drivers do not necessarily learn from previous accidents. A study of Spanish bus drivers showed that when a driver is involved in one accident, it increases the probability that he/she will have another accident (Blasco et al. 2003).

Road transport workers also have work tasks other than driving, for example, loading and unloading. Thus, there are other risks for them having an accident than just the risks involved in driving. Transportation workers in U.S. industries have the highest incident rate of slips and falls while at the same level (Yoon & Lockhart 2006). Truck drivers have an elevated risk of over-exertion since their work involves handling goods (Brooks 2008; Shibya et al. 2008). A U.S. study of 3053 accidents in the trucking industry showed that 14% of the accidents were due to over-exertion (Lin & Cohen 1997). A recent U.S. study of the trucking industry also found that truck drivers' injuries were most typically caused by lifting heavy objects, and the result was back, shoulder or arm/hand over-exertion or strains (Spielholz et al. 2008). In an Australian study, 321 short-haul transport drivers listed the top safety problems that they faced in their job; two-thirds of the drivers saw road and driving issues (the behaviour and presence of other road users and the potential for crashes) as an important safety problem, and almost half of the drivers reported lifting and manual material transfers as the biggest safety problems in their work (Friswell & Williamson 2010).

2.3.2 Accidents and risk factors at construction sites

It is challenging to maintain safety at a construction site at all times because of the continuously changing working environment and workers (Ciriello et al. 1999). Material transfers are an important part of construction work because new materials are needed all the time for construction and construction waste needs to be removed from the premises. Construction work is performed both outside and inside throughout the year. Risk-taking is sometimes even seen as a part of construction work (Kouabenan 2009).

A study at a Denver International Airport construction site showed that most (54.4%) of the 4000 reported injuries were attributed to victim factors, such as inappropriate actions, safety infractions, being in a hurry and inexperience. Environmental factors (i.e. weather, terrain, poor lighting, walking surface, and so forth) contributed to a third of all injuries. (Glazner et al. 2005)

Manual material transfers are common at construction sites. In addition to the risks for road transport, both manual and mechanical transfers include risks at construction sites (McKay 2010). Holt (2001) found that the risk of injury exists in manual materials transfers where heavy and differently shaped items are carried or lifted and the tasks may include twisting, stooping and poor postures.

An appropriate working environment is crucial for material transfers. Material transfer requires space and a tidy work environment so that it can be performed safely (Holt 2001). In a U.K. study of construction accidents, 49% were partly the result of poor housekeeping and problems with the site layout and space availability (Haslam et al. 2005). At another construction site, inadequate housekeeping and weather were considered to be contributing factors to trips and falls (Lipscomb et al. 2006).

Thorough planning of lifting operations, adequate training for those using the lifting equipment, and properly selecting and inspecting the lifting equipment are considered to be essential in improving the safety of the lifting operations at a construction site (Sertyesilisik et al. 2010). Tasks that demand lifting are associated with an increased risk of lower back pain. A French study of construction workers showed that 29% of occupational accidents were caused by handling and carrying objects (Chau et al. 2002). At the construction site at Denver International Airport, the workers who had accidents as a result of slipping or tripping reported that 11.5% of their accidents occurred when they were carrying objects (Lipscomb et al 2006).

How the work is designed is important at construction sites, where the working environment is changing all the time. A U.S. study stated that designers are not totally aware of ergonomics as an injury risk for construction workers (Sunwook et al. 2008). A Finnish study showed that most material transfer accidents at a construction site were due to over exerting work movements (Niskanen & Lauttalammi 1989).

Construction materials are often transferred from one place to another at building sites. Materials need to be transferred to the upper floors, even though the lower floors are still unfinished. Transferring materials to upper floors may be done by carrying them up stairways or by using an elevator or lifting device (i.e. a crane). Since the stairs and surfaces are also still being built, they may lack safe surfacing and railings, which causes a risk of an accident to workers (Lipscomb et al. 2006). Stairways increase the risk of falling and struggling with the materials. Steps can increase the risk of injury in addition to making movement more complex (Holt 2001). Stairway accidents occur, for example, because of poor lighting, the presence of debris, foreign objects or wetness of the treads (Jackson & Cohen 1995).

Using elevators decreases the risks that are caused by using stairs. However, elevators include risk factors as well. Major hazards from elevators include, for example, becoming caught in the opening to a car when the car moves, becoming caught in the doors and being trapped in a stalled car (Brauer 2006).

2.4 Improving occupational safety of material transfers

Occupational accidents are not an inevitable part of material transfer work. There are several things that can be done in order to prevent accidents. Everyone is responsible for their own occupational safety, but the legal responsibility is on the employer. Therefore, employers should always be alert to safety issues. Improving occupational safety includes paying attention to technical, organisational and human safety features (Harms-Ringdahl 2009).

Limited safety knowledge and a low motivation to follow the safety procedures increase the number of occupational accidents. It is conceivable that those workers who have a low motivation to follow safety rules and procedures in their work are also the ones who break the rules the most. Also, the workers with less safety knowledge probably break the safety rules most often. (Barling & Frone 2004)

2.4.1 Management's commitment to safety

Management's commitment to safety is crucial in improving occupational safety. This commitment involves continuously reflecting upon how the organization is going to manage risks, having adequate resources to manage risks (people, equipment, procedures, time), reinforcing safe behaviours, including assurances of worker and management competence, and putting in place mechanisms for limiting blame so that "uncertainty about it will not limit reporting and learning" from events that do occur (McDonald et al. 2009).

It is crucial to ensure adequate management safety practices and safety training in order to prevent occupational fatalities (Lu & Tsai 2008). The training of expert and novice workers seems to make transfer manoeuvres safer, especially in terms of reducing the amount of mechanical work done on the load and workers needing to use their backs (Gagnon 2003). For example, a forerunner transport company in Denmark has an introduction program during which newly employed drivers are introduced to a set of instructions concerning safety, including how to handle the goods, and newly employed drivers worked for at least one week with an experienced driver (Shibuya et al. 2010). Supervisors' interaction with employees in promoting safety causes employees to work with material transfers in a safer manner (Zohar & Luria 2003).

A study of port workers in Genoa, Italy found that a suitable training period, including professional training and job tutoring by experienced workers, is important in order to prevent accidents around the port, where huge volumes of materials are being transferred (Fabiano 2010). Haste contributes to an unsafe working environment, and this can be seen both in road work and at workplaces (Choudhry & Fang 2008). Management's commitment to safety was clearly demonstrated at a construction site in Colorado where the safety director was visibly committed to worker safety and supported workers who wanted to take extra time, if needed, to perform their work safely (McDonald et al. 2009).

2.4.2 Reduction of the risks

While some methods have been developed to foresee possible accidents, it is still impossible to reliably foresee all accidents (Attwood et al. 2006b).

Risk assessment should be performed in order to manage safety risks at work. It is also essential to learn from previous accidents and incidents in order to prevent future accidents. Regardless of the existence of various risk assessment methods, few of them are validated at the design state within the construction industry (Pinto et al. 2011).

The employer can improve the safety of material transfers by recognising and eliminating the hazards associated with the materials being transferred and by providing training for personnel (Maxwell et al. 2007). Material transfer accidents can be prevented by improving methods and finding better ways to operate (Heinrich et al. 1980). Training workers to use correct positions when lifting objects can help decreasing back injuries (Plamondon et al. 2006). Preferring two person manual transfer techniques and using appropriate tools and devices for material transfers at workplaces also help to prevent a risk of injury (Hess et al. 2010). On the other hand, having two persons transfer materials may introduce additional risk factors which will need further consideration (Holt 2001).

2.4.3 Organisational and technical measures

Occupational Health and Safety (OH&S) management systems support maintaining a healthy and safe working environment. An effective OH&S policy demonstrates the organization's commitment to safety. An Occupational Health and Safety system defines the safety responsibilities and helps an organization plan for continual improvement and design, develop and implement risk assessments and controls. (BS 8800 2004)

The incidents that occur during material transfers provide information that can be used for decreasing future manual transfer accidents (Lortie & Pelletier 1996). In order to decrease the risk of accidents in material transfers, it might be possible to reduce the object weights or strength requirements of a task and to increase the frequency of rest breaks (Gallagher 2005).

Breaks are important both in road transport and at workplaces (Perez 1999). Rest and recovery are important to construction work, especially when the work includes a large number of manual transfers (Holt 2001).

At a constructions site, the risk of injuries in manual material transfers can be decreased in the following ways:

- using mechanical assistance
- improving tasks (i.e. changing work routines, using teams, and so forth)
- using smaller packages
- improving the working environment (housekeeping, adequate lighting, and so forth)
- training workers for manual transfers (Holt 2009).

Organizational factors may be the cause of many accidents (Pate-Cornell & Murphy 1996). Management's role in improving occupational safety is important since it provides the resources for a safe workplace and makes workers feel comfortable by caring about safety issues at the workplace (Choudhry & Fang 2008). How the work is organised has a positive influence on occupational safety in road transfers; in other words, it is important for workers to have sufficient rest breaks, non-excessive working hours, sufficient staff to move goods safely and reasonable deadlines (Friswell & Williamson 2010).

2.4.4 Improving the working environment

Sweden is an example of a country which has invested in road safety by creating Vision Zero, with the basic idea that no one will be killed or seriously injured within the road transport system. The improvements to the traffic environment were performed, for example, by increasing the amount of space and barriers and by providing separate routes for pedestrians and bicyclists. Vision Zero began in 1997 and by 2006 the number of road fatalities had decreased from 6/100000 inhabitants to 4.7/100000 inhabitants. (Johansson 2009)

The working environment plays a remarkable role in promoting occupational safety in material transfers. Improving the working environment, for example by ensuring suitable lighting and clear workspaces and by avoiding changes in floor levels, are ways of reducing the risk of slipping or having an underfoot accident whilst transferring a load (Davies et al. 2003).

3 THEORETICAL FRAMEWORK AND OBJECTIVES OF THE STUDY

3.1 Theoretical framework

Accident causation theories have identified different factors that play a role in accidents. The domino theory of accident causation explains that "*the occurrence of a preventable injury is the natural culmination of a series of events or circumstances, which invariably occur in a fixed and logical order. If this series is interrupted by the elimination of even one of the several factors that constitute it, the injury cannot possibly occur*". The updated version of the domino theory includes the role of management as a crucial factor and explains that "*tactical errors in employee behaviour and work conditions are seen as arising from operational errors made by managers and supervisors*". (Heinrich et al. 1980)

In addition to the domino theory and its updates, the first accident theories are based on human behaviour. It was assumed that certain persons were more likely to have an accident. The life change unit theory proposes that accident liability depends on life events: people are more liable to be involved in an accident at some points in time than at others. The motivation reward satisfaction model proposes that the safety performance of the employee is dependent upon his/her level of motivation and his/her ability to perform. (Heinrich et al. 1980)

Human errors have been seen as a cause of accidents (Heinrich et al. 1980). People have a tendency to make mistakes and, when this tendency is combined with the particular circumstances that exist in a workplace, it may result in an unsafe action (Reason 1997). The risk of an accident grows when workers act in unsafe ways (Reason 1990). Many everyday operations become automatic, without people considering the risks (Wagenaar 1994). The factors behind accidents are related to the workers, the working environment and the organization (Attwood et al. 2006a).

Today, accidents are believed to occur as a result of the complexity of people's activities. In addition to accident prevention, other goals also are involved. This means that there is a possibility that the goals might conflict. (Woods et al. 2010)

The working environment is also one factor that has an influence on occupational accidents (Heinrich et al. 1980). According to the "unsafe act" theory, 85–95 per cent of accidents occur because of unsafe actions, and the remaining 5–15 per cent are a result of unsafe working conditions (Petersen & Goodale 1980).

Organizational factors have a significant influence on workers' safety (Mullen 2004). Management has the key responsibility for accident prevention (Heinrich et al. 1980). It makes decisions which affect safety and production goals and, in terms of short-time interest, there is a possibility that safety goals are not fully realized because of production pressures (Reason 1990). The following accident case is an example of an incident in which a serious accident was caused because of all three elements: the worker, the working environment and management.

A serious road accident occurred in Konginkangas, Finland in 2004 where a bus collided with a heavy vehicle which was loaded with paper reels. In the collision, 23 persons were killed. The investigating committee found that several factors contributed to the accident. The planning of the schedules for both vehicles was done so that it was not possible to drive them by following the prevailing speed limits or rules for driving and rest times. Both vehicles were driving over the speed limit and at too high a speed for the weather conditions. It is possible that the driver of the heavy vehicle had a reduced state of alertness because of the late hour of the accident and the driver's previous driving history of having worked four consecutive night shifts. The investigating committee stated that drivers cannot be held responsible as the only ones creating traffic risks. The risks also seemed to be inherent in the hauliers' operating culture. In addition to drivers and hauliers, the other links in the transportation chain can also be regarded as factors impeding traffic safety. Their assignments and demands can generate overly tight schedules and haste, which increase the risks in traffic and in loading and unloading work. (Accident Investigation Board of Finland 2004)

People have a reason for acting as they do. The way they act makes sense given their goals, their knowledge and their level of attention at the time. People have conflicting goals which affect the way they act (Woods et al. 2010). For example, drivers may have conflicting goals in terms of avoiding the costs of late deliveries (speeding, not having breaks), avoiding actions that would lead to lawsuits (not following the regulations regarding rest times), or maintaining good relations with fellow workers and supervisors.

A catastrophic process accident at BP's Texas City Refinery in Texas City in 2005 is an example in which the goals of meeting safety requirements and lowering costs conflicted. The accident resulted in 15 deaths and more than 170 injuries. The safety review panel found several organizational factors and safety deficiencies that contributed to the accident. Some employees had been working overtime, since the company had a reward system that allowed it, and they were probably fatigued. The panel believed that process safety risks may have increased because of workers working excessive hours. (Baker et al. 2007)

According to resilience theory, occupational accidents are a result of a change in workers' performance. Since the performance of humans is not totally stable, technology should be built in such a way that human errors do not lead to an accident (Hollnagel 2007). Resilience engineering has to do with the breakdowns in the adaptations necessary to cope with the complexity rather than with human error. Instead, safety is seen as a positive thing, as the presence of something (Woods et al. 2010). Resilience means being resilient or robust when events and demands do not fit preconceived and routinized paths (Woods et al. 2010). In the transportation process there are many forms of variability, for example conflicting goals, dilemmas, irreducible forms of uncertainty, coupling, escalation and the potential for surprise (Woods et al. 2010).

The theoretical framework of this study is shown in Figure 2. Recognizing the factors behind occupational accidents in material transfers helps in terms of finding ways to improve the occupational safety of material transfers.

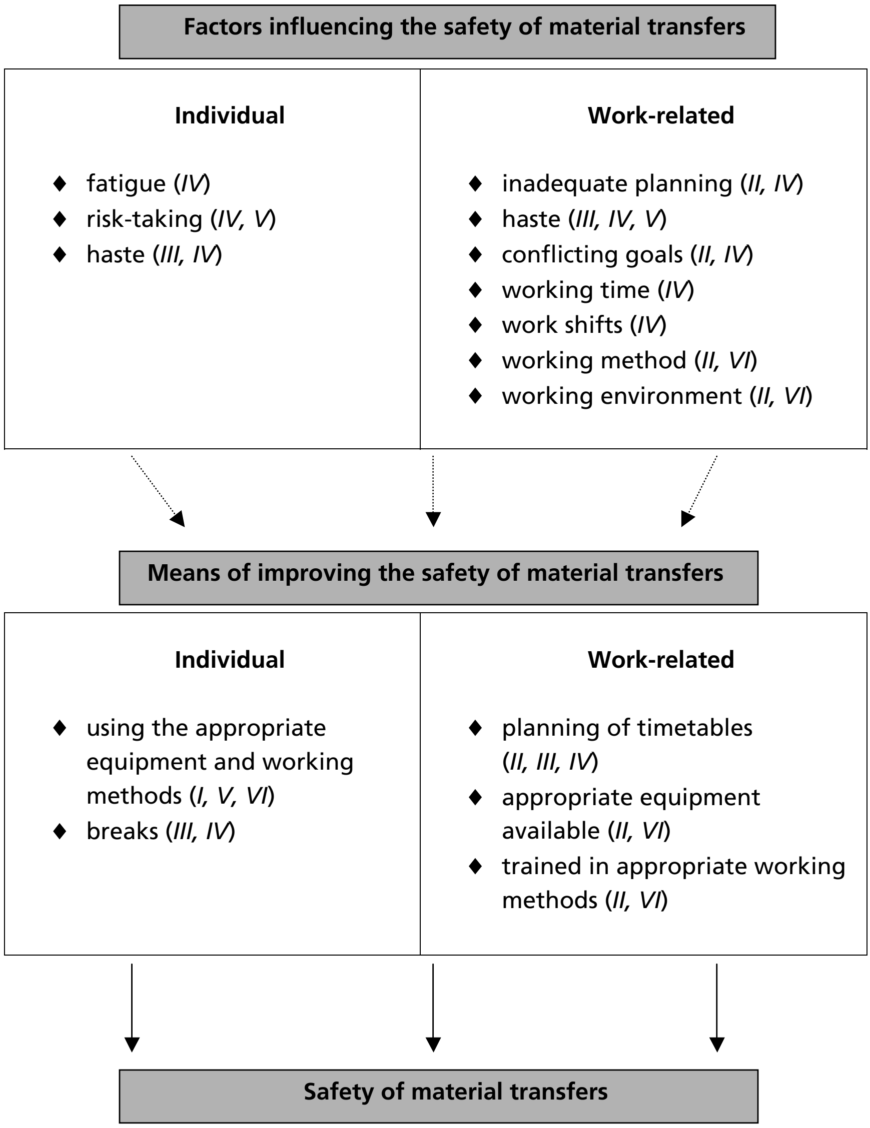

Figure 2. Factors influencing occupational accidents in material transfers and the means of improving the safety of material transfers

The factors behind material transfer-related accidents are both worker and work-related. In order to improve the safety of material transfers, both aspects should be considered. Utilising appropriate means of transfers, as well as careful planning and rationale scheduling of material transfers, reduces the risk of occupational accidents occurring.

3.2 Objectives

The main objective of this study is to improve the occupational safety of material transfers. The approach involved discovering which factors have an influence on occupational accidents and what can be done to prevent occupational accidents. The sub-studies concentrate on occupational accidents in material transfers during road transport and at a construction site. Figure 3 shows the progress of the study, when each sub-study was conducted and the connections between the sub-studies.

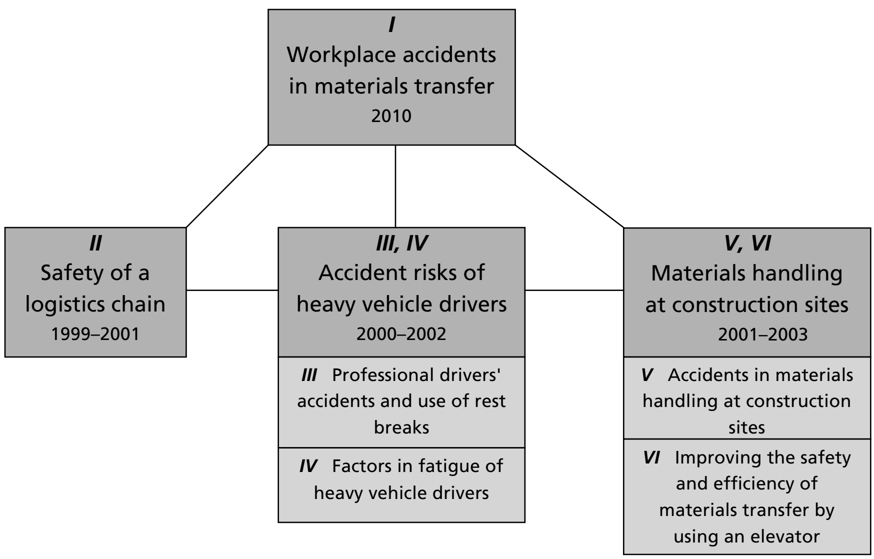

Figure 3. The progress of the study and connections between the sub-studies and logistics safety. The year refers to when the sub-studies were conducted.

In order to discover the factors underlying material transfer-related accidents, the research project assumed several sub-goals:

- to show the proportion of workplace accidents that are related to material transfers in Finland, and whether or not they are more serious than other workplace accidents; to compare the factors contributing to material transfer-related accidents to other workplace accidents
- to discover the main risks and underlying causes of occupational accidents and material damage to the entire logistic chain
- to examine the effect of rest breaks on accidents by professional drivers
- to identify the heavy vehicle drivers' work-related and driver-related factors that affect the fatigue and momentarily falling asleep while driving
- to analyse what kinds of accidents occur in material transfers at a construction site and to find out whether the causes of minor accidents differ from those of serious accidents
- to show how well an integrated transport system at a construction site improves occupational safety and efficiency and diminishes demanding physical tasks.

4 MATERIALS AND METHODS

The thesis consists of six sub-studies in the field of logistics. We studied the occupational safety of logistics using the database of national accident statistics in order to get an overview of the breadth of the study issue. Using an entire logistic chain as a viewpoint showed the broad array of safety concerns in the logistics of paper transportation. We studied the inside logistics of workplaces using a construction site as a model and road logistics from the viewpoint of professional drivers. We did not include taxi drivers in the study group. In the sub-study *IV*, we further limited the study group of professional drivers to heavy vehicle drivers (i.e. bus drivers and van-drivers were excluded).

The measures to improve occupational safety in all of these sub-studies were widely discussed in each sub-study's steering group and by the researches of these sub-studies. We only conducted a safety intervention at a construction site where different transfer aids were compared.

We obtained the data on occupational accidents from the national occupational accidents and diseases statistics database maintained by the Federation of Accident Insurance Institutions (FAII). The FAII functions as the coordinating organ for all the organizations engaged in statutory accident insurance. Every insurance company handling statutory accident insurance in Finland must be a member of the FAII. According to the Employment Accidents Insurance Act (1948/608), the member institutions are obliged to provide the FAII with the information necessary for compiling and maintaining statistics.

Table 3. Description of the databases for occupational accidents used in this study

Source of accident information	Description of the source	The source was used in the original paper, No. (year used)
Sammio	The database of occupational accidents. The database consists of the accident reports on occupational accidents. The database was referenced based on a CD and only the accidents that were serious (i.e. caused disability longer than 30 days) were studied.	*V* (2002)
Register of occupational accidents and diseases (TAPS)	Register of occupational accidents and diseases. The database consists of the reports established by the District Safety Authority.	*V* (2002)
Web-based database on occupational accidents and diseases (Tapaturmapakki)	The web-based database for all the compensated occupational accidents and diseases in Finland.	*I* (2009)
TOTTI	The database for fatal occupational accidents in Finland between 1985 and 2009. The database consists of the accident reports on fatal occupational accidents at workplaces.	*I* (2009)

The databases of occupational accidents used in this study are listed in Table 3. After the year 2005, the Sammio database became the web-based Tapaturmapakki database, which includes the same information that Sammio used to have. The database includes those occupational accidents and diseases where compensation was paid. Occupational diseases were excluded from this study.

4.1 Workplace accidents in material transfers

We studied the workplace accidents related to material transfers in Finland and compared them to other workplace accidents (*I*). The study was conducted using available statistics and data regarding occupational accidents and fatal accidents in Finland. We chose to use data from two databases: 1) fatal accident reports (1985–2009) and 2) official statistics on occupational accidents in Finland (2003–2007). We chose this five-year period for occupational accidents in order to see whether the proportion of material transfer-related accidents remained stable. Because of the lower number of fatal accidents, we examined all of the fatal accidents as a single group.

4.1.1 Fatal occupational accidents

The database on fatal occupational accidents (TOTTI) contains approximately half of the fatal occupational accidents in Finland between 1985 and 2009. The reports on the fatal occupational accidents are located at FAII's public web pages (FAII 2009). The fatal occupational accidents included in the database are cases which have been examined by an external investigator. The investigation group is established after information about the fatal accident has reached FAII. The accident investigation is based on an in-depth-study. The investigation group gathers information about the accident and the factors that caused the accident. The full accident report is written on the basis of the investigation. The report includes a great deal of information about the accident and what factors influenced it and how similar accidents can be prevented in the future. The occupational accidents that are not included in the data on fatal occupational accidents are as follows: traffic and commuting accidents and accidents where violence or intoxicants were involved. Traffic accidents are not included in the data on fatal occupational accidents because they are investigated by different teams co-ordinated by the Finnish Motor Insurers´ Centre.

At the time when the research for this project was conducted (December 2009), the database consisted of 807 fatal accidents which had occurred in Finland between 1985 and 2009. The researchers read the description of each fatal accident and chose those accidents involving material transfers for further analysis.

We analyzed whether or not the fatal accident was involved in material transfers. We independently estimated the reliability of the classification by arriving at a consensus among two researchers. Their rate of consensus was 86.7%, which is above the acceptable level of 70% (Litwin 1995).

Further analysis of the material transfer-related accidents consisted of evaluating the information about which task was being performed when the accident occurred and the cause of the accident on the basis of the report. We used the information from the analysis when selecting the variables from the accidents statistics (4.1.2).

4.1.2 Occupational accident statistics

The FAII database on occupational accident statistics includes all of the compensated occupational accidents and diseases in Finland. The compiled statistics provide information on work-related accidents and the occupational diseases, injuries and illnesses caused by them, the types and amounts of compensation paid to each recipient, the factors influencing the amount paid, and information on the policyholders, their sphere of business, the actual payroll and their insurance premiums.

We made a comparison between the accidents that occurred as a result of material transfers and those that did not. The accident statistics were examined during a five-year-period (2003–2007).

We chose from the statistics those accidents which had occurred as a result of material transfers by using certain ESAW variables (European statistics on accidents at work) (European Commission 2001). Variables that did not belong to material transfers were excluded. The ESAW variables that we chose as belonging to material transfers are presented in Table 1 in the original paper *I*. To compare material transfer accidents to other accidents, we deducted the number of material transfer accidents from all occupational accidents.

The variables under examination between all workplace accidents and workplace accidents involving material transfers included the length of disability time, gender, age, branch of business and injury type. The comparison was made using a statistical test (chi-square).

4.2 Accidents in a logistic chain

Logistic chains are usually examined on the basis of their productivity. Here, the focus was on occupational safety and preventing material damage throughout the entire logistic chain. The material is based on data from a case study (*II*) about the transportation of paper conducted between 1999 and 2001. We chose paper transportation because, at the time when the study began, wood industry products were the most transported types of goods in Finland when measured by tonne-kilometres (Statistics Finland 1999).

Six companies were involved in the paper logistic chain that we studied. The operations were as follows: storage at the paper mill, transportation by railway, outbound harbour operations, the vessel, inbound harbour operations, and truck-trailer delivery. The process began at a paper mill in central Finland and ended at a harbour in Germany and the amount of transferred paper was 77 000 tons of paper per year in that specific logistics chain.

The sub-study consisted of:

- collecting the accident and damage statistics directly from the companies studied
- identifying the critical points of enhanced risk in the logistic chain on the basis of the data collected and interviews: all phases of the logistic chain were observed by the research team in detail and included interviews with 4–5 employees from each participating company about the accident and damage risks. In the interviews, one employer at a time was asked about the main risk points for occupational accidents and material damages at the workplace
- creating some new ways of calculating the costs of unwanted events:
  - dividing the repairing process for damaged paper reels into minor tasks and estimating the time spent on each minor task. Based on the total amount of time spent on the repairing process, the costs were calculated
  - allocating the costs of occupational accidents in relation to how many tons of paper were handled at each phase of the logistic chain in order to show how many monetary units were spent on accidents per ton handled
- establishing working groups in order to improve the safety of the logistic chain.

4.3 Road transport

We studied the accident risks of heavy vehicle drivers. We gathered the study material (*III, IV*) from the questionnaire in the study "Rest places of heavy traffic – present situation and improvement needs". The study was conducted in 2001–2002. The questionnaire was mailed to 3 000 professional drivers from the registry of a voluntary professional drivers' safety organization. This voluntary organization is the largest when counting the number of members in Finland and it has no political or labour market goals.

The questionnaire was created by the research group with the assistance of the research steering group. The questionnaire included 52 questions on the following categories:

- background information about the driver (2 questions)
- background information about the company (2 questions)
- working experience and working information (7 questions)
- health and fatigue status (4 questions)
- amount of sleep and working times (5 questions)
- accidents and accident factors (5 questions)
- breaks and rest places (27 questions).

We did not ask about sleep disorders in this study. We sent one pilot survey to 50 drivers and created the final questionnaire on the basis of our experience with the pilot questionnaire.

The anonymous questionnaire was completed by 720 drivers (i.e. response rate 24%). Of the respondents, 3% were women and 97% men. The mean age of the drivers was 38.6 years. Two out of three respondents had been a professional driver for over ten years, and 59% of drivers drove long distances between cities, whereas 41% drove in the city area.

We compared all of the respondents (N=720) on the basis of their having been involved in accidents. The questionnaire inquired about whether or not they had been involved in an accident as follows: Have you been involved in a traffic accident at work during the past year?

The questionnaire included a question about the type of vehicle that the respondents mainly drive. Based on the responses, we divided the respondents into heavy vehicle drivers and other drivers. We studied the factors behind fatigue and momentarily falling asleep while driving based on the responses by the drivers, most of whom primarily drove trucks, buses or trailer trucks (N=683).

We performed chi-Square tests to test the differences between 1) fatigued and non-fatigued drivers, and 2) drivers who had fallen asleep while driving and drivers who had not. The measure of the effect size was performed using Cramers-Phi. We calculated the odds ratios and their p-values for different factors pertaining to driver fatigue. Multivariable logistic regression models were performed on the risk of fatigue and falling asleep while driving. The models were adjusted for: length of work shifts within a 24-hour period; whether drivers were capable of following driving and rest-time regulations; whether drivers were able to choose the time for their breaks (always, sometimes or never); health; and, the amount of sleep that drivers got before their shifts. We performed all statistical analyses using the SPSS statistical program.

In order to get a general overview of occupational accidents for heavy vehicle drivers, we gathered the information from official statistics on occupational accidents (2005–2008) in the FAII database (FAII 2010b). We compiled the information for the accidents for lorry and articulated vehicle drivers based on the severity of the accident, deviation and the types of injuries.

4.4 Safety of logistics at a construction site

We also studied the safety of material transfers at construction sites. We gathered the study material (*V, VI)* from the following sources:

- serious accidents (i.e. accidents that resulted in disability leave of 30 days or more) were selected from the databases (Sammio and TAPS) on the accident reports for occupational accidents by using a keyword search; the search provided 102 serious accidents related to material transfers at construction sites that had happened between 1987 and 1998.
- company accidents during a period of 18 months (1 January 1998 – 1 July 1999) at a large Finnish construction company; 355 reported occupational accidents happened, of which 114 (32%)

occurred during the transfer of materials. Company accidents were minor accidents (i.e. accidents that resulted in disability leave of less than 30 days).

- experimental material and an analysis of efficiency which was collected at a construction site located in Paris, France where a ten-floor residential building was built; the data collection and measurements took place at one staircase where the permanent elevator was operating during the finishing phase.

In order to get a general overview of occupational accidents suffered by construction workers, we gathered the information from the official statistics on occupational accidents (2005–2008) in the FAII database. We compiled the information for accidents suffered by construction workers based on the severity and deviation of the accident and the types of injuries.

On the basis of the Finnish construction company's 114 accident reports, we divided the information on each case into seven categories. The classification variables were as follows: type of accident, type of injury, body part injured, tool, work activity, construction product and outcome of the accident. We encoded and analysed the classified data using a statistical program (SPSS). Two researchers encoded the information from the accident reports for 50 accident cases to ensure the reliability of the classification. In each category, the percentage of identical classifications varied between 92% and 100%, which is above the acceptable level of 70% (Litwin 1995). Table 4 gives an example of how the classification was performed for one accident case where a worker injured his back while lifting wall boards.

Table 4. Example of how one accident case was classified based on the Finnish construction company's accident reports

Description of accident:
a worker was lifting partition wall boards and injured his back.

Classification variable	Encoded variable
Type of accident	over-exertion
Type of injury	dislocation or sprain/strain
Body part injured	back
Tool	manpower
Work activity	vertical transfer, manual
Construction product	building boards
Outcome of the accident	3–30 days of sick leave

We also evaluated safety, health and efficiency at a construction site in Paris, France. Two researchers collected the data. Workers used a spiral staircase for manual transportation. In addition to manual transportation, they used an elevator for the other two transfer systems. The components of the advanced systems included a small pallet-sized (60x60 cm) SAFETIpallet (which is half of the size of the European standard pallet) and a device for horizontal transfers. The transfer systems that we measured were as follows:

- Manual (products are carried manually using the stairs)
- Manual + Elevator (products are carried manually to the elevator floor and then again to the installation site)
- SAFETIpallet + Horizontal mover + Elevator (products are loaded onto the pallet, which is then transferred with the aid of the horizontal mover to the elevator, lifted to the required floor and transferred again to the installation site).

The products that we measured were ceramic wall tiles packed in cardboard boxes and plumbing items (toilet seats and water tanks) for bathrooms. The transfer of the products during on-site observations began on the ground floor and ended up five floors higher.

We determined efficiency using MatSim in order to reach our objectives. MatSim is a simulation method which is based on Factory Flow™ static simulation software; it is a method for experienced users. The Factory Flow software runs on top of AutoCAD™. Prior studies have used the MatSim method in various cases for analysing the safety, effectiveness and economics of transportation; here, we modified the method so that it could be used as a tool for construction sites in order to take into account both horizontal and vertical movement.

We analysed ergonomics and safety using the SAFERtool. It is a method for experienced users. The SAFERtool is an analysis method for assessing the safety and ergonomic features of transportation systems at a construction site. It was constructed in the form of Excel worksheets so that it could be easily adapted to fit different solutions. The safety module evaluates safety and environmental factors and analysis is done by assessing the risk levels of separate work phases.

4.5 Summary of the study papers

The methods explained in the previous paragraphs are presented in more detail in the six sub-studies. The studies are related to the occupational safety of material transfers. Part 1 of the study consists of two study papers. Paper I presents the breadth of the accidents involved in material transfers based on the accident statistics. The proportion of material transfer-related workplace accidents were calculated from fatal and non-fatal accidents. Paper II presents the idea of taking the entire logistic chain into account when considering unwanted events, in other words, occupational accidents and material damages. The results are based on a case study of paper transportation.

Part 2 of the study consists of two study papers concerning accidents and risk factors for heavy vehicle drivers. Paper III presents the low use of rest places as a risk factor for accidents. Paper IV presents the factors behind fatigue and momentarily falling asleep at the wheel for heavy vehicle drivers. The ability to choose the time for breaks turned out to be a significant factor in terms of decreasing the risk of accidents and fatigue.

Part 3 of the study consists of two study papers concerning material transfers at construction sites. Paper V shows the results of material transfer-related accidents from compiled statistics and at a construction company. The comparison between minor and serious accidents showed the different factors behind the accidents. Paper VI presents the idea of utilising devices for transferring materials at construction sites. A comparison is made between carrying building products manually on the stairs and by using an elevator. Table 5 summarises the three parts of the study and the papers. The main objectives, methods and results are also presented.

Table 5. Description of the papers used in the doctoral thesis

	Part 1 Accidents in materials transfer and improving the safety of logistic chains		**Part 2 Accidents and risk factors for road transportation**		**Part 3 Improving materials transfer-related accidents at construction sites**	
	Paper I	**Paper II**	**Paper III**	**Paper IV**	**Paper V**	**Paper VI**
Title	Workplace accidents in materials transfer in Finland	The safety of a logistics chain – case study	Use of rest breaks and accidents by professional drivers	Factors in fatigue of heavy vehicle drivers	Accidents in materials handling at construction sites	Improving the Safety and Efficiency of Materials Transfer at a Construction Site by Using an Elevator
Publisher	Journal of Occupational Safety and Ergonomics (accepted for publication)	Logistics Research 2 (2010) 159–163	Perceptual and Motor Skills 101 (2005) 665–668	Psychological Reports 108 (2010) 1–8	Construction Management and Economics 21 (2003) 729–736	Journal of Construction Engineering and Management 132 (2006) 836–843
Authors	Perttula P., Salminen S.	Perttula P.	Salminen S., Perttula P., Merjama J.	Perttula P., Ojala T., Kuosma E.	Perttula P., Kiurula M., Merjama J., Laitinen H.	Perttula P., Korhonen P., Lehtelä J., Rasa P-L., Kitinoja J-P., Mäkimattila S., Leskinen T.
Objectives	to compare material transfer-related accidents to other workplace accidents	to discover the main risks and underlying causes of occupational accidents and material damage in the entire logistic chain	to examine the effect of rest breaks on accidents by professional drivers	to identify the work-related and driver-related factors that affect the fatigue of heavy traffic drivers	to analyse the causes of minor and serious accidents occurred in material transfers	to compare an integrated transport system to manual transfer for improving occupational safety and efficiency

Table 5. continues

Table 5. continues...

	Part 1 Accidents in materials transfer and improving the safety of logistic chains		**Part 2 Accidents and risk factors for road transportation**		**Part 3 Improving materials transfer-related accidents at construction sites**	
	Paper I	**Paper II**	**Paper III**	**Paper IV**	**Paper V**	**Paper VI**
Methods	Analyses of the statistics and data regarding occupational accidents and fatal accidents	The case study's accident statistics were collected from the companies studied	Questionnaire and analysis of the responses	Questionnaire and analysis of the responses	Analyses of minor and serious accident reports	Observing the data from a construction site
Results	The proportion and comparison of material transfer-related accidents with respect to all workplace accidents	The risk points for occupational accidents and material damages in the entire logistic chain	Comparison between accident-free drivers and drivers involved in accidents	Recognized factors behind drivers' fatigue and falling asleep at the wheel	The proportion of material transfer-related accidents compared to all accidents at a construction site and a comparison of minor and serious accidents	Comparison of health and safety risks when utilising different modes of transfer
Conclusions	One quarter of workplace accidents occurred in material transfers.	The highest accident rates were in harbour areas and most of the material damages occurred in harbour areas.	The accident-free drivers could choose the timing of their breaks more often than did drivers who were involved in accidents.	The length of the work shifts was an essential work-related factor affecting driver fatigue.	Material transfers caused more serious accidents than other work activities at construction sites.	The lowest accident risk involved workers using a tool for horizontal transfers and an elevator for vertical transfers.

5. RESULTS

5.1 Occupational accidents in logistics

In order to determine the number of material transfer-related workplace accidents, we compared data from two different sources: fatal accident reports and official accident statistics from FAII databases. The results from these databases show that at least one quarter of occupational accidents occur during material transfers.

5.1.1 Fatal accidents

Altogether, we studied 807 fatal accident reports, 202 (25%) of which were related to material transfers. Table 6 shows the most typical tasks that were being performed when the accident occurred and the most typical causes of the accidents. Mechanical material transfer (horizontal and vertical) was the most typical task resulting in fatal material transfer-related accidents; it resulted in accidents in 24% of the 202 cases. The most typical cause of an accident (26% of the cases) occurred when the victim remained under load.

Table 6. Most typical tasks when fatal workplace accidents occurred and causes of fatal material transfer-related workplace accidents when considering 202 accident cases between 1985 and 2009, analysed from the database of fatal accidents

	Number (n) and share (%) of fatal accidents	
Task	n	%
vertical mechanical transfer	37	18
loading	25	12
unloading	22	11
manual transfer	19	9
work with conveyer	17	8
horizontal mechanical transfer	13	6
Cause	n	%
remained under load	53	26
remained under transmitter	40	20
fell from height	36	18
compressed to transmitter	23	11
unassisted transmitter	19	9

Examples of fatal workplace accidents included:

- A construction worker carrying waste to a bin on the 6th floor and falling to the ground from an opening in the guardrail;
- A worker removing a disruption from the conveyor system and being crushed when the conveyer system began to move;
- A worker being run over by a forklift that was transferring material at the workplace.

5.1.2 Non-fatal occupational accidents

The total number of reported workplace accidents in Finland between 2003 and 2007 was 538 159. The number of material transfer-related accidents in the same period was 145 816. The share of material transfer-related workplace accidents was 26.9–27.5% of all workplace accidents in Finland between the years 2003 and 2007 (Table 7). While the number of workplace accidents has increased, the proportion of material transfers-related workplace accidents has not varied much.

Table 7. The proportion of material transfer-related workplace accidents compared to all workplace accidents in Finland between the years 2003 and 2007, analysed from the compiled national statistics

Year	Number of material transfer-related workplace accidents	Number of workplace accidents	% of material transfer-related workplace accidents
2003	25965	96221	27.0
2004	26138	96299	27.1
2005	29920	110927	27.0
2006	31089	115705	26.9
2007	32704	119007	27.5

The length of disability varied depending on whether or not the accidents were related to material transfers or not. Workplace accidents related to material transfers represent a greater proportion of the workplace accidents causing disability leave of 4–30 days (Table 8). The difference is highly significant ($p<0.001$).

Table 8. The length of disability caused by material transfer-related workplace accidents and other workplace accidents in Finland between 2003 and 2007, analysed from the compiled national statistics

Length of disability [days]	Material transfer		Not material transfer	
	%	frequency	%	frequency
more than 30	7.5	10875	8.5	33508
15–30	9.0	13156	8.4	33002
7–14	20.6	30035	17.3	67830
4–6	17.6	25659	13.7	53793
0–3	45.3	66091	52.0	204210

Gender differences are significant in material transfer-related accidents ($p<0.001$). Of all 538 159 workplace accidents, 389 392 happened to men, which is equal to 72.4%. When comparing those workplace accidents which were related to material transfers to those which were not, it was found that a majority (76.3%) of material transfer-related workplace accidents happened to men.

Material transfer-related workplace accidents occurred more typically among workers aged 20–49 (Figure 4). In contrast, workplace accidents that were not related to material transfers occurred significantly more often to workers over 50 years of age. The difference is statistically significant ($p<0.001$).

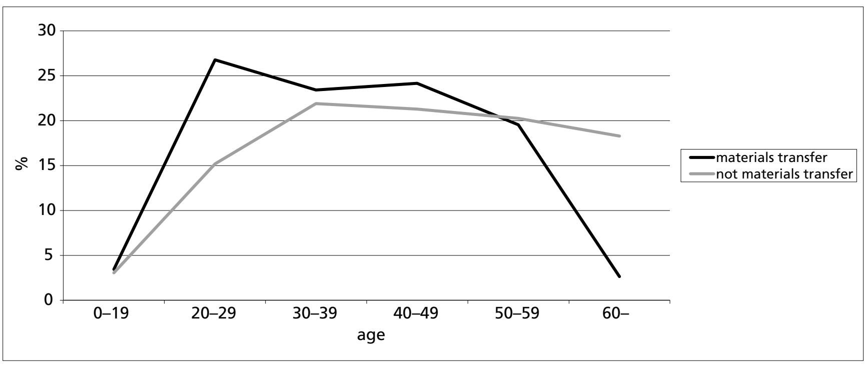

Figure 4. Age distribution of those workplace accidents related to material transfers and those that were not related to material transfers in Finland between 2003 and 2007

The main branches of business in which most of the material transfer-related workplace accidents occurred were manufacturing, construction, the wholesale and retail trade, transport, storage, communication and the municipal sector. The least number of workplace accidents – both material transfer-related and not – occurred in extra-territorial organizations, fishing, mining and quarrying and private households. The difference is highly significant ($p<0.001$). The biggest difference between workplace accidents related to material transfers and those not related to material transfers was in wholesale and transport, where the number of material transfer-related accidents was higher.

The most typical injuries in non-fatal material transfer-related workplace accidents were dislocations, sprains and strains. Wounds and superficial injuries were the most typical types of injuries in workplace accidents not related to material transfers. The difference is statistically significant ($p<0.001$).

5.2 Occupational accidents and material damages in logistic chains

More focus should be put on broadening the examination of accidents that occur in logistic chains. It is not sufficient to address occupational safety at the level of isolated organizational units only. The functions and working methods involved in the previous phases in a logistic chain have a great impact on the subsequent phases. The causes of the injuries and the material damages may be the same, but the statistics are usually kept separately. Thus, the general effects of the incidents may disappear, making it difficult to estimate them.

In the sub-study of a logistic chain *(II),* some points of high risk were identified: most of the material damages occurred in harbour areas and the highest accident rates were also in harbour areas (Figure 5). On the other hand, the greatest number of lost work days per accident occurred on ships.

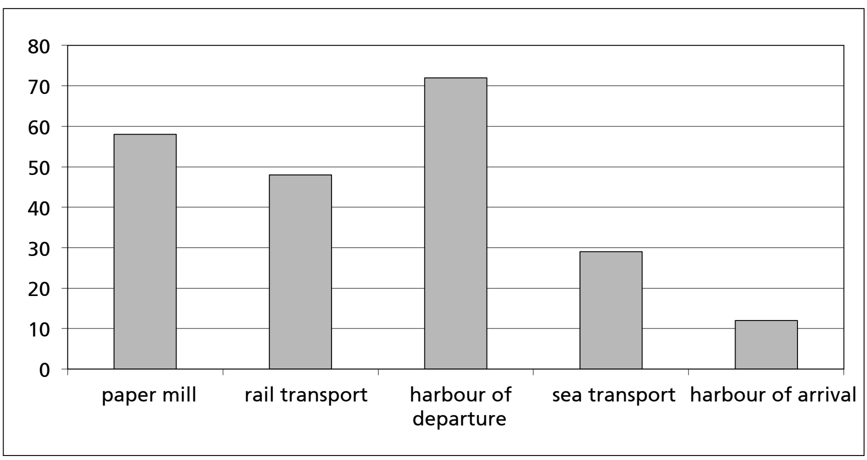

Figure 5. Accident frequencies (number of accidents / working hours in millions) in the different phases of a logistic chain

Occupational accidents were responsible for 26% of the costs of the unwanted events in the logistic chain that we studied, while material damages were responsible for 58% of these cost (Figure 6). We calculated the monetary values of property damages and grade-crossing accidents based on the proportion in tons of the transported materials. When considering the total amount of the logistical costs, the results showed that the monetary value of occupational accidents accounted for one per cent of the supply chain costs.

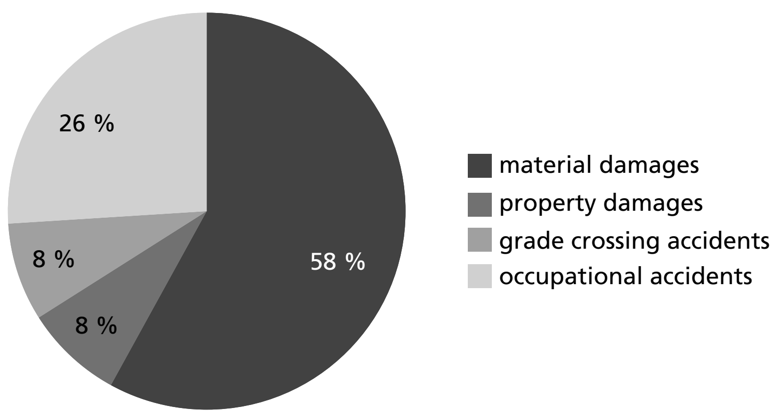

Figure 6. The calculated distribution of the costs of the unwanted events in the logistic chain

The interviews with the employees revealed some risk factors at different phases of the logistic chain. Risks were involved in the working methods, the work environment and the tools that were used. On the basis of this study, the harbour of departure began to organize a safety management system. It launched a program to cut down on occupational accidents.

Approximately one per cent of the paper reels were damaged at some stage of the logistic chain. In the chain studied, most of the material damages occurred at the harbour. However, most of the damage was not noticed until the paper reels reached the customer. Although each step in the process of handling and repairing a damaged reel takes little time, it took almost an hour to repair one paper reel. This incurs considerable costs, and these costs are passed on to the customer. The working group was established to help prevent material damage at every stage of the logistic chain. The members of the working group represented the entire logistic chain from the paper mill to the harbour of departure.

The ability of employees to see the importance of noticing and reporting material damages as early as possible turned out to be an important issue. Job rotation and rearranging the tasks was one way of ensuring the understanding of the workers. One problem was that employees received no information regarding the number of damaged reels that were sent forward from their phase of the logistics chain and the total extent of damage to the reels. It also became evident during this study that more instruction was needed regarding the handling of different types of paper. The flow of information was not considered to be adequate; instructions concerning the handling of new paper materials did not always reach the later stages of the logistic chain. Finding ways to improve information flows throughout the entire logistic chain remained an important issue for the working group.

5.3 Occupational safety of professional drivers

Finnish professional drivers were studied using a questionnaire. The study focused on whether the drivers had been involved in a traffic accident at work during the past year and whether the drivers felt ever fatigued while driving.

The results of the analysis indicated that drivers of lorries and articulated vehicles were involved in 22 806 occupational accidents between the years 2005 and 2008 (FAII 2009). Approximately three per cent of these accidents occurred while commuting. Table 9 shows the severity of occupational accidents for lorry and articulated vehicle drivers.

Table 9. Severity of occupational accidents for lorry and articulated vehicle drivers between 2005 and 2008, analysed from the compiled national statistics

	Year					
Length of disability [days]	**2005**	**2006**	**2007**	**2008**	**Tot.**	**%**
>30	786	796	750	767	3099	13.6
15–30	713	703	635	620	2671	11.7
7–14	1133	1217	1141	1082	4573	20.1
4–6	883	862	862	843	3450	15.1
0–3	2050	2251	2382	2330	9013	39.5
Tot.	5565	5829	5770	5642	22806	100

Half of the occupational accidents for lorry and articulated vehicle drivers occurred while movement (including being aboard the means of transport) and one quarter during loading, unloading and storing. One-third of the drivers' accidents were because of falling and slipping. More than 40% of the injuries to drivers involved dislocations, sprains and strains, and concussion and internal injuries.

In the questionnaire used as a part of this study, we asked heavy vehicle drivers which factors they see as the most important factors for accidents and near-miss cases; they could choose several factors related to themselves, other road users and other mitigating factors (Table 10). The most common answer (chosen by 76% of the drivers) was that other road users do not consider the characteristics of stopping and acceleration for heavy vehicles. Drivers saw their own speed as a risk factor, as well as other road users' overtaking them on the road and poor weather conditions.

Table 10. Most important factors for accidents and near miss cases reported by drivers. The values represent the percentages for the factors chosen by the drivers in each group

	Fatigued N=189	Non-fatigued N=490	All drivers N=683
Self			
too high speed	58	74	69
fatigue	59	31	39
speaking on the mobile phone	19	13	14
Other road users			
overtake	66	64	64
do not consider the characteristics of stopping and acceleration	77	77	76
Other factors			
weather	69	71	70
condition/maintenance of road	52	54	53
haste	44	32	35

5.3.1 Use of rest breaks and accidents

Of the 720 drivers, 11% had been involved in at least one traffic accident at work within the past year. These 81 drivers had been in 101 accidents. The drivers involved in those accidents were younger than the accident-free drivers. They were also less experienced as professional drivers. The gender of the driver was not related to whether or not they had been involved in an accident.

Over half of the respondents drove trucks and double trailers; however, those drivers who had been involved in accidents drove delivery vans, buses and other vehicles more often than the accident-free drivers. On the other hand, drivers driving trucks with a single trailer were less often involved in accidents.

The accident-free drivers answered that they can choose the timing of their breaks more often than did drivers who were involved in accidents. Two out of every three drivers liked to visit cafes during their breaks.

5.3.2 Factors behind driver fatigue

More than one-fourth (27.8%, n=189) of the respondents often felt fatigue during their work shifts. Drivers who felt fatigue reported having significantly more difficulties in staying vigilant while driving than did non-fatigued drivers (χ^2=78.35, df=2, p<0.001).

Factors related to driver fatigue included too little sleep, poor health and personal reasons (Table 11). Personal reasons included, for example, lack of sleep because of small children at home and nutrition. The number of fatigued drivers varied according to the size of the company. Larger companies had more fatigued drivers than small companies (χ^2=10.23, df=3, p<0.01). There was no statistical difference in driver fatigue based on gender, age, length of work experience or regular/irregular routes.

The length of the work shifts was an essential work-related factor affecting driver fatigue. Of the fatigued drivers, 70.6% (n=130) reported not always being able to follow driving times and break-time regulations during their work; among non-fatigued drivers, the percentage was 45.8% (χ^2=40.98, df=2, p<0.001). Nearly a third, 31.6% (n= 216), of drivers reported that they were not always able to follow the break-time regulations because of inadequately planned timetables. Drivers who are never allowed to choose the timing of their breaks themselves have seven times greater risk of experiencing fatigue, while drivers who only sometimes can choose the timing of their breaks have 2.4 times greater risk of experiencing fatigue than those who can choose the timing of their breaks (Table 12). Understandably, those drivers whose working day is 16 hours or longer have 4.2 times greater risk of experiencing fatigue than drivers whose work shift is 10 hours or less within a 24 hour period.

Table 11. Factors behind driver fatigue

	Fatigued (N=189)		Non-fatigued (N=490)	
Work-related factors	**N**	**%**	**N**	**%**
Length of working shift in 24 hours period				
10 hours or less	16	8.5	104	21.3
10–14 hours	110	58.5	310	63.4
14–16 hours	36	19.1	49	10.0
16 hours or more	26	13.8	26	5.3
Capable of following the driving and rest time regulations				
always	54	29.3	264	54.2
sometimes	111	60.3	209	42.9
never	19	10.3	14	2.9
Possible to choose the time for a break				
always	68	36.0	316	64.5
sometimes	104	55.0	162	33.1
never	17	9.0	12	2.4
Employer or customer takes into account the breaks				
always	42	22.6	185	37.9
sometimes	76	40.9	193	39.5
never	68	36.6	110	22.5
Driver-related factors				
Health status				
good	70	37.0	297	60.7
satisfying or bad	119	63.0	192	39.3
Amount of sleep before starting to work				
5 hours or less	30	15.9	34	6.9
5–7 hours	127	67.2	279	56.9
7 hours or more	32	16.9	177	36.1
Less than 3 hours sleep before driving				
often	25	13.2	18	3.7
sometimes	118	62.4	256	52.5
never	46	24.3	214	43.9

Table 12. Risk of fatigue among heavy vehicle drivers

	Unadjusted		Adjusted	
Work-related factors	**Odds ratio**	**p**	**Odds ratio**	**p**
Length of working shift in 24 hours period				
10 hours or less	1.00		1.00	
10–14 hours	2.31	<.001	2.12	<.05
14–16 hours	4.78	<.001	3.79	<.001
16 hours or more	6.5	<.001	4.19	<.005
Possible to choose the time for a break				
always	1.00		1.00	
sometimes	2.98	<.001	2.38	<.001
never	6.59	<.001	7.02	<.001
Driver-related factors				
Health status				
good	1.00		1.00	
satisfying or bad	2.63	<.001	2.45	<.001
Amount of sleep before starting to work				
5 hours or less	4.88	<.001	3.15	<.005
5–7 hours	2.52	<.001	2.42	<.001
7 hours or more	1.00		1.00	
Less than 3 hours sleep before driving				
often	6.46	<.001	2.59	<.05
sometimes	2.14	<.001	1.44	n.s.
never	1.00			

Of the respondents, 27.5% (n=188) reported that during the last year they had momentarily fallen asleep while driving. Of these drivers, 47% (n= 88) also reported often feeling fatigue while driving (χ^2=10.67, df=2, $p<0.01$). The respondents reported that the factors behind momentarily falling asleep while driving were work-related and driver-related. Those drivers who reported working longer than 16 hours have 4.4 times greater risk of falling asleep while driving than those drivers who work 10 hours or less within a 24 hour period. Driver-related factors behind momentarily falling asleep while driving included the health status of the drivers and a short amount of sleep before beginning work.

5.4 Occupational safety at construction sites

The results of the analysis indicated that construction workers were involved in 36 521 workplace accidents between 2005 and 2008 (FAII 2010b). Table 13 shows the severity of occupational accidents for construction workers.

Table 13. Severity of workplace accidents for construction workers between 2005 and 2008, analysed from the compiled national statistics

Length of disability [days]	Year				Tot.	%
	2005	2006	2007	2008		
>30	888	897	937	905	3627	9.9
15–30	847	791	886	802	3326	9.1
7–14	1693	1714	1843	1625	6875	18.8
4–6	1259	1278	1365	1261	5163	14.1
0–3	4001	4289	4670	4570	17530	48.0
Tot.	8688	8969	9701	9163	36521	100

Almost one quarter (24%) of the accidents suffered by construction workers had to do with falling and slipping and 15% were because of over-exertion. The most common types of injuries for construction workers were wounds and superficial injuries, dislocations, sprains and strains, and concussion and internal injuries.

5.4.1 Accidents at a construction site in Finland

On the basis of the analysis of the Finnish construction company's accident reports, we found that 32% of the accidents occurred in material transfers. However, 36% of the days in which workers were absent from work were a result of accidents that had occurred in material transfers. Material transfers had thus caused more serious accidents than other work activities at construction sites ($t=-2.44$, $df = 351$, $p< 0.005$). Table 14 shows the distribution of accident types based on the study material.

Table 14. Distribution of accident types from among all accidents at a construction site, minor material transfer-related accidents in a 18-month period (1998–1999) and serious material transfer-related accidents at construction sites from a database on occupational accidents (1987–1998)

Type of accident	All accidents at a construction site N=355, %	Minor material transfer accidents N=114, %	Serious material transfer accidents N=102, %
over-exertion	27	49	0
falling, collapsing objects	7	9	40
falling from a height	6	3	38
injury caused by handled object	17	16	12
flying particles and objects	15	0	0
falling down, slipping	13	11	1
stepping on objects	4	4	0
injury caused by moving object	4	3	2
injury caused by stable object	2	2	0
electricity, heat, radiation, harmful substances	1	1	1
other	4	2	6

The minor accidents at a construction site were mostly due to over-exertion. Of those accidents resulting from over-exertion, the part of the body that was injured was most typically the back or the legs. Over-exertion occurred most often when an employee was performing a manual transfer of materials. The results from the database on serious accidents showed that such accidents were mostly due to falling and collapsing objects and falling from a height. Objects fell mostly during horizontal transfer. Accidents resulting from falling from a height occurred, for example, when a worker was carrying material at a height (e.g. on a rooftop) or assisting in lifting work.

Serious accidents and non-serious accidents had different causal factors (i.e. work activity, the type of tool used and the particular construction product handled at the moment of the accident) and consequences (i.e. type of injury, length of disability). These differences are presented in Table 15.

Table 15. Comparison of material transfer-related accident factors for minor accidents (from the company's accident reports) and serious accidents (from the national database on occupational accidents) at construction sites. The percentages show the proportion of the factors for both categories

	Minor accidents N=114	Serious accidents N=102
Type of accident	over exertion 49%	falling, collapsing objects 40% falling from a height 38%
Type of injury	dislocation or sprain/strain 38%	undefined (fatal accidents included)
Body part injured	back 25%	other (majority lead to death)
Tool (tool that was used at the moment when the accident happened)	manpower 59% devices (e.g. chains) 24%	manpower 22% devices (e.g. chains) 20% cranes 19%
Work activity (task during which the accident happened)	manual horizontal transfer 40% manual vertical transfer 36%	mechanical vertical transfer 24% loading and unloading 15%
Construction product (what kind of item was handled when the accident happened)	building boards 11% structure completing products 9%	concrete products 22% metal products 19%
Length of sick leave	3–30 days 79%	death or permanent disability 35%

In all of the company accidents, the injured body parts were typically the palm of the hand and the fingers (16%), the eyes (14%) and the back (12%). But when considering the company's accidents that pertained only to material transfers, the back was the body part that was injured most often (25%).

Most typically, no actual tool was being used when the accident occurred, so the tool was categorized as manpower. In the company's materials transfer-related accidents, 59% occurred when manpower was the only tool used. Almost all (97%) of these manpower-related company accidents occurred during manual transfers. In 22% of serious accident cases, the tool used was manpower and the work activity in most of these cases was horizontal or vertical manual transfer; likewise, the object handled in most of these manpower cases was a concrete product or a building board.

The task during which the accidents happened in company's materials transfers were mostly (47%) during horizontal transfer operations. A total of 40% of them happened during horizontal manual transfers and more than half of those accidents were due to over-exertion. Vertical manual transfers were performed in 36% of the company's material transfer-related accidents.

In 11% of the material transfer-related accidents, the construction product being transferred was building board, and in 8% of the accidents the materials being transferred were timber products. Most (58%) of the accidents related to the building boards were due to over-exertion, and most of these accidents happened during horizontal or vertical manual transfers. Of the more serious material transfer-related accidents, 23% occurred while concrete products were being transferred and 19% when metal products were being transferred. A total of 48% of the accidents related to concrete products resulted from falling and collapsing objects.

A total of 63% of workers fell into the sick leave category of 3–30 days. In material transfer-related company accidents, 79% of workers fell into the category of 3–30 days. The share of the accidents that resulted in disability leaves of less than three days at construction sites was smaller in material transfer than in the construction industry in general (Table 16). The disability leave after accidents related to material transfers was longer (average 9.4 days) than for other work activities (average 7.7 days).

In the company that we studied, 355 accidents resulted in 2945 days of disability leave. The accidents that happened during material transfers (114 accidents) resulted in 1071 days of disability leave. Thus, the accidents that happened during material transfers alone caused 36% of the outcome of the accidents in the construction company. This shows that accidents related to material transfers are more serious than other accidents.

Table 16. Outcomes of accidents in the construction company under study and the database on serious accidents

Length of sick leave or extent of disability	No. of all company accidents	No. of company's-materials transfer -related accidents	No. of serious accidents from database
Less than three days	121	20	3
3–30 days	222	90	34
1–12 months	12	4	27
More than 12 months or permanent handicap 10–60%	0	0	2
Death or permanent disability over 60%	0	0	36
Total	355	114	102

5.4.2 Improving the safety and efficiency of material transfers at a construction site

We calculated the risk indexes for different transfer systems at a construction site. We found that the highest risk indexes involved manually carrying materials in stairways, and pushing and pulling the loaded horizontal mover over obstacles. (Table 17.)

Table 17. Combined Risk Indexes calculated as cubic average values using the SAFERtool

Combined risk indexes	Products		
Transfer systems	**Ceramic tiles**	**Toilet seats**	**Water tanks**
Manual	1.57	1.58	1.08
Manual + Elevator	0.95	0.87	0.68
Safeti pallet + Horizontal mover + Elevator	0.74	0.79	0.49

We calculated the combined risk indexes for the task time, which differs according to the different transportation systems. Health and safety risks were at their highest when transporting materials manually at construction sites. The risks decreased when vertical (an elevator) and horizontal (a wheeled device) transportation aids were used. The risks were at their lowest when transportation was performed in an integrated way with minimal manual material transfer.

Efficiency here refers to the efficiency of material transfers of three different products. Thus, it does not include the efficiency of the entire construction site. A similar improvement can be seen in the efficiency results as was the case with the health and safety risks: the working time needed after introducing the elevator was 41% of the purely manual handling time, and after introducing the horizontal mover the work only took 15.5% of the time to complete than it had previously (Table 18). The complementary effect is the direct saving of time as compared to walking in the stairways.

Table 18. Delivery system efficiency for ceramic tiles: unit times and times it took to deliver all products for one level (measured times from ground floor to installation floor and relational efficiency)

	Relational efficiency	
Ceramics delivery	**Unit time**	**%**
Manual	3 min 27 s	100
Manual + Elevator	1 min 25 s	41.1
Safeti pallet + Horizontal mover + Elevator	32 s	15.5

Introducing the elevator led to a significant improvement in the health and safety level and in efficiency. Introducing the combined use of the horizontal mover + elevator further led to considerable improvement in the health and safety level and in efficiency.

6 DISCUSSION

The number of occupational accidents that occur as a part of logistics is considerable. In Finland, one quarter of occupational accidents that led to death occurred during material transfers. The example of the construction site showed that material transfer-related accidents result in longer periods of disability leave than other workplace accidents. Of all occupational accidents, more than half result in disability leave of 0–3 days, but when considering only material transfer-related accidents, the percentage is 45.3. Thus, the importance of improving the occupational safety of material transfers and transportation is indisputable.

The importance of an entire logistic chain is indisputable when considering the economical aspect. In previous studies about logistic chains, the issue of occupational safety for the most part does not come up. Chopra & Sodhi (2004) found a variety of risks in supply-chains ranging from low-impact to high-impact risks, and claimed that those risks are probably greatest when considering the financial effects on the company. The present study also emphasises improving occupational safety in logistic chains in order to reduce unwanted costs and human pain. The well-known risks in logistic chains, such as delays and material damages, may also lead to occupational accidents. From the economic perspective, the costs of occupational accidents are unnecessary.

A crucial factor in improving occupational safety in logistics is managing the transfer of materials. The factors behind occupational accidents during road transport and at construction sites are for the most part the same, for example fatigue and over-exertion. Choosing appropriate devices and transport equipment decreases the need for manual material transfers. The injuries caused by over-exertion are painful for workers, causing harm in everyday life. This is why it is important to find solutions to decrease the risk of over-exertion. Mechanical transfer equipment increases the risk of collisions at workplaces. The working environment and design of the work should be planned in such a way that accidents can be prevented.

6.1 Road transport

This study presents the results from a questionnaire completed by 720 Finnish professional drivers. Those professional drivers who were involved in accidents less often were able to choose their break times. This result is also supported by a French study, which found a significant increase in the risk of occupational road accidents when drivers were unable to choose their work rhythm (Fort et al. 2010). Regulations are designed to provide guidelines for improving the occupational safety of drivers and general traffic safety, like regulations regarding driving and rest times. At any rate, it is evident that those regulations are violated every now and then. The drivers know the regulations, but still they violate them.

Without a doubt, drivers, like all workers, would enjoy having breaks during their shifts. Still, there must be a reason why the regulations are not followed. The professional drivers in this study answered that haste is the main reason for not following the regulations. Breaks should be taken into account more often when planning transportation deliveries; they should be taken into account at different phases of the planning, during the buying of transportation and in the drivers' decision-making.

Prior studies disagree on whether or not age is related to driver fatigue. This study does not find any significant correlation between age and fatigue among heavy vehicle drivers. Similarly, a study of commercial goods drivers in 17 countries also did not find the age of the driver to be significantly associated with experiencing fatigue problems (Adams-Guppy & Guppy 2003).

This study showed that 28% of heavy vehicle drivers often felt fatigue while driving. The proportion of fatigued drivers was almost the same in a U.K. study of male drivers, of which 29% reported feeling close to falling asleep while driving (Maycock 1997). Fatigue is a well-known factor behind sleep-related accidents. A recent Finnish study found that more than 80% of fatigue-related crashes did not involve personal injuries

(Radun & Radun 2009). At any rate, this finding does not make fatigue safer. We cannot ignore the fact that 20% of such crashes still resulted in personal injuries.

The finding from present study was that 27.5% of heavy vehicle drivers who responded reported momentarily fallen asleep while driving. This finding does not differ much from a U.S. study in which 25.4% of truck drivers reported falling asleep at the wheel during the previous year (McCartt et al. 2000). A result that caused concern was that only less than half of the drivers who had momentarily fallen asleep while driving also reported often feeling fatigued while driving. The other half of the drivers who responded having momentarily fallen asleep while driving probably do not recognise their fatigue. It is also surprising how many respondents reported that the length of the working or driving time exceeded the maximum allowed by the regulations.

Different expectations from various parties may increase the pressure for drivers to get the work done quickly and this is probably one reason why drivers take the risk of violating the regulation for driving and rest times. Mullen (2004) also found that coercive pressure to get the work finished as quickly as possible sometimes leads to unsafe working behaviour, which in this study is seen as driving without adequate breaks. This is a challenge for employers who are, on the one hand, responsible for worker safety as well as following the laws and regulations, but, on the other hand, need to pressure workers to work as quickly as possible to meet deadlines. One reason for violating the regulations may be the same as Forward (2009) found: that the risk of an accident is minor compared to the benefit of violating the regulations, that is to say, saving time.

Another study on construction sites also found that workers considered the risk of injury to be very low (Choudry & Fang 2008). A Danish study found that truck drivers were aware of safety instructions concerning moving a wagon, but still they violated the rules for convenience or to save time (Shibuya et al. 2010). On the other hand, Kirschenbaum et al. (2000) stated that those workers who knowingly broke the safety regulations reported worse working conditions than did non-violators. Studies have also shown that longer driving distances increase the possibility that drivers will commit errors or violations (Özkan et al. 2006).

Brauer (2006) stated that truck drivers who drive for ten hours have nearly a two times greater risk of a crash compared to drivers who have been on the road for less than two hours. A Belgian study of truck drivers found that unrealistic work schedules were significantly associated with poor quality of sleep (Braeckman et al. 2011). This study found that when a work shift is between 10–14 hours long, the risk of momentarily falling asleep is almost three times greater than for those drivers whose working shift is less than ten hours long. Thus, according to previous research and this study, it is presumable that long working shifts are dangerous for heavy vehicle drivers. And, in addition to the drivers, long working and driving shifts cause a risk to other road users as well. A sad example of this is the Konginkangas accident, in which the driving schedules were unrealistic.

Preventing sleep-related road accidents is challenging. Sagberg (1999) stated that it is important to raise awareness of the risks caused by fatigue. It is essential that both driver and employer recognize the risks. Basically, while the employer cannot affect personal factors that have an influence on driver fatigue, this study has shown that there are also work-related factors underlying driver fatigue. The employer can reduce driver fatigue by making the schedules so that drivers can have enough breaks and by encouraging drivers to take breaks instead of driving when feeling fatigued. The present study shows that the drivers' risk of fatigue and momentarily falling asleep while driving as well as being committed to accidents decreases when the drivers have a possibility to choose their break times. Thus, it is obvious that it is possible for an employer to improve working conditions, which, in turn, also increases the possibility of safe work.

New technology has increased the tasks for heavy vehicle drivers. Now, while driving, they must simultaneously use monitors and mobile phones. Using mobile phones is common while driving, and there is an increased risk of having an accident when drivers speak on the phone while driving (Backer-Grondahl & Sagberg 2010). A study by Bener et al. (2010) showed that the risk of violating safety regulations was higher for those drivers who used mobile phones while driving. In one study, almost half of the drivers who reported using mobile phone while driving also reported experiencing dangerous situations while using a phone (Pöysti et al. 2005). On the other hand, those results also showed that phone-related accidents have not increased in line with the growth of the mobile phone industry. Mobile phones are also a safety device for drivers who may face an emergency situation while working alone.

Road transfers are performed in different circumstances. In recent years, it has not been only the Nordic countries that have had to deal with snow. A Canadian study found a significant link between road surface conditions and road safety (Ushman et al, 2010). Weather conditions increase the risk of crashes (Brijs et al. 2008). Environmental conditions also increase the stress levels of drivers (Hill & Boyle 2007). Weather conditions do not necessarily increase severe road accidents, but they may increase non-fatal and property-damage crashes, which cause delays in the transfers (Koetse & Rietveld 2009). In addition to the maintenance of roads, it is also important to take weather conditions into consideration when planning transfers. Driving speed should also be adjusted to fit weather and road conditions; additionally, drivers may need to take breaks more frequently when forced to also concentrate on the weather conditions.

Heavy vehicle drivers identified other road users as the main factors in road accidents and near miss cases. Similar to our study, an Australian study also found that professional drivers saw the behaviour of other road users as an important safety problem (Friswell & Williamson 2010). Stanton & Salmon (2009) came to the same conclusion, finding that drivers considered other road users causal factors when accounting for driver error. Probably the heavy vehicle drivers see a lot of near miss cases involving other road users, since they spend a lot of their working time on the roads. However, it is essential for the workers to also recognize their own risk factors.

Barriers help reduce road accidents, for which Sweden provides a good example (Johansson 2009). While technical solutions offer a good way of improving traffic safety, they are not enough. A very important factor for road safety involves reducing excess haste along roadways. Haulers and their customers are in a key position to ensure that heavy vehicle drivers need not be in such a hurry. A conflict of interests arises when materials should be transported safely and at the lowest possible costs, while at the same time trying to meet unrealistic schedules.

6.2 Material transfers at construction sites

The construction industry is one of the most dangerous industries. Choudhry & Fang (2008) found that managers are able to see a wider array of risks at a construction sites than workers. This may be one reason why workers may underestimate the risks involved in material transfers if they do not consider their actions to pose a risk. This study showed that 32% of occupational accidents at a Finnish construction site occurred during material transfers and these accidents accounted for 36% of the absence days.

The present study compared serious accidents and non-serious accidents and found that they had different causal factors (i.e. work activity and the tool used and the construction product being handled at the moment of the accident) and consequences (i.e. type of injury, length of disability). The causation of fatal accidents and non-fatal accidents has been studied earlier and, in support of Petersens' causation hypothesis, researchers found that the causation factors were different between fatal and non-fatal accidents (Salminen et al. 1992).

Various products are handled at construction sites. Products are heavy and the shape of the products varies, and sometimes it is challenging to find a safe way to transfer the products. In particular, the appropriate tool should be used when transferring heavy and inconvenient products. This study showed that in terms of manual material transfer-related accidents at construction sites, in most cases the work activity involved a horizontal or vertical manual transfer; also, in most of these cases the object being handled was a concrete product or a building board.

Over-exertion is a common type of injury at construction sites. This study showed that workers injured their backs most often (25%) during material transfer-related accidents at a construction site. The present study also showed that using appropriate devices in material transfers at construction site increases ergonomics, safety and efficiency. Lin & Cohen (1997) also found this to be true and they suggested that over-exertion can be decreased by making appropriate devices available for workers. Villaneuva & Garcia (2011) also suggested in their study that the organisation of work and the planning of breaks is an important issue in terms of preventing accidents.

The present study calculated the accident risks for working with different material transfer equipment. When the task was to transfer construction materials to the upper level of a building, we calculated that manual material transfer is the most time-consuming method and has the greatest risk of accidents compared to using mechanical help.

The lowest accident risk involved workers using a tool for horizontal transfers and an elevator for vertical transfers.

Careful planning of the transfers and maintenance of transportation equipment are essential when preventing accidents. Tidiness and order around the working environment are crucial as well. Using appropriate devices for material transfers at construction sites helps save time and decreases the ergonomic risks.

6.3 Improving occupational safety in material transfers

Most findings from this study are in line with previous studies. In preventing material transfer-related occupational accidents, there are several things that various parties (i.e. employer and employee) can do. Management's role is crucial to improving occupational safety. According to a Canadian study, young workers in particular felt that workplace injuries are part of the job and speaking up about safety shortcomings in the workplace was seen as complaining (Breslin et al. 2007). This sort of attitude puts a lot pressure on management because these young workers represent the experienced workers of the future. The attitude towards safety can be created by company policies. And, as Lundberg et al. (2010) stated, the corrective actions that will be taken into account when preventing similar accidents will also depend on the resources available.

Motivating employees to improve safety is challenging, especially in today's fast-paced society. Petersen & Goodale (1980) wrote in their book that the manager's task is not to motivate workers, but to offer them the opportunity to be motivated. A good way to improve employees' involvement is to listen to what they have to say about their work and safety (DeJoy 1994). Kouabenan (2009) also found that involving ordinary workers in accident analysis increases their knowledge about accident causation and also improves their understanding of safety measures and promotes greater adherence to those measures. The present study of logistic chains showed that the involvement of members from all organizational levels in working groups improves understanding about the reality of the job, the resources available and commitment to improving safety.

The importance of logistic chains is widely known. Logistic chains are mainly studied on the basis of productivity and efficiency of processes, but occupational safety has not usually been included in such studies. Winkler (2009) included human potential as an important part of supply chain management; by human potential, he meant management and the training challenge.

The main objective of this study was to find the factors behind material transfer-related accidents. In order to prevent these accidents, it is first essential to recognize them. The employer's role in gathering and using the information about the occupational accidents that have occurred is key when a company seeks to learn from past accidents. An Australian study found that only a small proportion of road transport accidents may be reported and, thus, only a very small proportion are investigated (Salmon et al. 2010). This may be due to the possible desire of drivers to avoid reprisals (i.e. punishment or increased insurance costs). In Finland, it may also be a challenge for employers to create the type of open atmosphere in which workers view all accidents as important and report them. Small companies may not see the benefit of reporting an accident as worth the time and effort spent on the paperwork.

The occupational health care unit often has information about accidents and work-related illnesses of the employees. Medical checks of workers could also include consultations regarding the possibilities of performing material transfers more safely. Better co-operation between the occupational health care unit, the employer and employees is one way of improving working conditions. Material transfer-related accidents should not be seen as an inevitable part of workers' "bad luck", because they are more likely things that can be prevented. Once the occupational health care unit has the information about accidents and health status of the workers, the health care unit should use the information by consulting the employer, for example, about the importance of work time arrangements and appropriate material transfer equipment.

It may be difficult for workers to express their dissatisfaction or concern about work time arrangements or inadequate material transfer equipment. Workers can also bring their concerns to the occupational safety and health committee, which exists in companies that have more than 20 employees. The occupational safety and health committee is party to sharing the information between workers and employers in order to improve occupational safety, for example in logistics.

In addition to driving, drivers face accident risks during loading and unloading operations. Many of these operations are performed in clients' workplaces, and thus the working environment is not familiar to drivers. The importance of adding clear signs about where to stop the vehicle for loading or unloading decreases the need for unnecessary driving in the client's workplace area. Additionally, when drivers are forced to focus their attention on looking for the right place to load or unload materials, it decreases their level of attention to the overall environment. In addition to an unfamiliar working environment, loading and unloading are often performed under tight schedules; in such circumstances, haste and probably the lack of appropriate devices may increase risk-taking. Drivers' orientation should include information on the risks at clients' workplaces, e.g. the unfamiliar work environment and internal traffic of the workplace.

It is recommended that material transfer tasks be redesigned so that workers might use the appropriate devices and working methods. Similarly, a U.S. study on industrial manual materials handling found that the tasks should be redesigned in such a way that they minimized hand distances, decreased the loads for lifts, lowers and carries, decreased the frequency of tasks and the distances needed for carries, pushes and pulls (Ciriello et al. 1999).

The importance of taking breaks is also supported by Sanati et al. (2010); they found that most of the occupational accidents in a factory occurred within three hours of the beginning of the work shift and they suggested that short breaks might decrease the likelihood of accidents.

Workers who are at the beginning of their work life are at a higher risk of being involved in material transfer-related workplace accidents. This is why orientation, accurate working methods and appropriate equipment for material transfers need to be properly introduced from the very beginning. Improvements to the work environment (i.e. suitable lighting and clear workspaces and routes) are important in order to avoid workplace accidents during material transfers. Even though different opinions exist regarding the effectiveness of training on lifting and handling in preventing back pain (Martimo et al. 2008), this study supports the training of workers in safe working methods. Generally speaking, material transfer-related accidents can be prevented by improving methods, by finding better ways to operate and by training personnel.

It is not sufficient to address occupational safety at the level of isolated organizational units only. The functions and working methods of the previous phases in a logistic chain have a great impact on subsequent phases. Co-operation between all parties in the entire logistic chain is essential in order to improve occupational safety. At construction sites, co-operation between different parties is essential because of the large volumes transported to and from the sites. A good layout design and planning can significantly reduce the risk of material transfer accidents.

This study provides the perspective of accident prevention in material transfers. Previous studies do not generally take this perspective into account. The consideration of the entire logistic chain in order to promote occupational safety is quite new in the study field of logistics. The results of this study can be utilised when considering risks and when planning material transfer.

6.4 Theoretical perspective

This study supports Attwood et al.'s (2006a) theory that the working environment is a factor in occupational accidents. During material transfers at construction sites, in particular, the working environment may pose several risk factors: untidiness, poor lighting or wet or slippery route surfaces.

This study supports the importance of organizational factors when preventing occupational accidents. When studied from the point of view of material transfers, it becomes clear that management has an important role in ensuring the resources for a safe working environment. The resources may include, for example, adequate devices for material transfers at construction sites, as sub-study *VI* showed, or reasonable schedules for heavy vehicle drivers to perform road transport safely, as sub-study *IV* demonstrated.

Human errors as a causal factor for occupational accidents can result from organizational factors, for example as a result of long working hours. Wagenaar's theory (1994) about people conducting routine tasks without considering the risks is supported by the sub-study on heavy vehicle drivers *(IV)* who drive on the roads while feeling fatigued. Also, the perspective of conflicting goals is supported by the sub-studies on heavy vehicle drivers *(III, IV)* who have their schedules determined by the clients and employers contrary to their own need for breaks.

The sub-study on the logistic chain (*II)* supports the domino theory. If there is an unwanted event (i.e. an accident or material damage) during any phase of the logistic chain, it has an influence on later phases of the logistic chain.

6.5 Limitations

Hoyos and Zimolong (1988) stated in their book that accidents are often reported by persons other than the victims. In Finland, workplaces fill in the accident reports, and send the report to an insurance company to get monetary compensation. The report forms are filled in by certain person at a workplace, and it is usually a different person than the victim (i.e. a supervisor or a secretary). The accident report is based on the description of the victim or eyewitness. National statistics are based on reports about accidents in which a particular party received compensation. Thus, it is obvious that accident statistics do not include all occupational accidents. It is presumable that not all of the accidents that occur at small companies are listed in the national accident statistics because, for the enterprisers, insurance is voluntary. The reports on fatal accidents are a result of the investigators' findings and it is possible that sometimes the reports, which include conclusions, may be a compromise on the part of the members of the investigating committee; it is also possible that these reports sometimes do not provide enough information.

We performed the sub-study of material transfer-related workplace accidents in Finland by making assumptions about whether the accidents were related to material transfers or not. Since there was no immediate way to find this out from the statistics, the researchers decided to make assumptions on the basis of deciding which ESAW-variables clearly were not involved in material transfers; then, they estimated that the remaining accidents were involved in material transfers. Still, there is a possibility that some of these accidents were not related to material transfers.

The low response rate (24%) in the questionnaire for professional drivers raises the question of whether or not the results can be generalized. It is possible that the questionnaire primarily appealed to drivers who suffered from insufficient rest breaks. The study material consists of the responses of professional drivers from the registry of a professional drivers' voluntary organization. This organization includes drivers who belong to a trade union and drivers who do not, as well as entrepreneurs. The respondents represent different transportation sectors and come from different sized enterprises. Thus, they are a fair representation of Finnish heavy vehicle drivers. Still, because of the low response rate, the results probably cannot be generalized without question. At any rate, the results provide an incontrovertible result based on the 720 drivers who completed the questionnaire.

In the sub-study of accidents at construction sites, we completed the search using a keyword search. The search focused on the accident reports written by investigators. The description of the accidents varied and the system did not link any keywords to the cases. Despite using various keywords when conducting the searches, it is obvious that not all accidents related to material transfers at construction sites were found.

6.6 Future research

At the time when the sub-studies included in this thesis were conducted, resilience thinking (Hollnagel et al. 2006) was not widely studied. If resilience thinking would have been as common then as it is today, it probably would have had an effect on the framework of the sub-studies. In addition to the risk factors that were studied, we probably would have studied the normal safety procedures and activities more intensively. Also, we probably would have conducted a survey on the actions taken in the case of emergencies if resilience thinking would have been more common.

For example, it would be interesting to survey heavy vehicle drivers again taking resilience thinking into account. The factors regarding driver fatigue did not come as a surprise. After the sub-study, the serious accident in Konginkangas occurred and it received a great deal of publicity because of the huge number of victims. The issue of fatigue was one of the factors that the media discussed. Revising the survey of heavy vehicle drivers would show whether any improvements have been made after that tragic accident. The survey could be improved in such a way that resilience thinking would somehow be included. It might be important to do a case-study on a company that does not allow its drivers to work overtime in order to increase information about the monetary issues involved in material transfers.

We only performed interventions at a construction site where different ways of transferring construction products were compared. The influence of the suggested safety improvements was not included in the sub-studies, and thus it is not known whether safety has improved at the case sites. The statistics show that over-exertion is still a typical type of injury at construction sites. Thus, we suggest that an intervention study could be done in the future to improve manual material transfers by teaching workers different transfer techniques and the importance of teamwork when transferring heavy objects.

7 CONCLUSIONS

This study shows that even though there are a lot of occupational accidents in material transfers, there are several things that can be done in order to prevent those accidents. The employer is mainly responsible for preventing accidents during material transfers, but several things also depend upon the workers. The risks caused by material transfers should be recognised by employers, the occupational health service and workers in order to co-operate in improving working conditions.

The increasing amount of materials currently being transferred from one place to another also raises the question of occupational safety. Within a single workplace, there may work employees from several companies. Workplaces have a need to improve the safety of their inside logistics because of the increased amount of materials being transported. For example, at construction sites there are heavy vehicles bringing new materials and taking away the trash, construction workers transferring materials and, in the meantime, a lot of materials are being stored that will soon be used. To manage the safety of these transfers, the design of the working environment needs to be planned in such a way that the transfers can be performed safely.

The working environment at construction sites should be planned in such a way that heavy vehicles have a safe route along which to transport the material. Loading and unloading of the heavy vehicles needs to be carried out in a place where the risks to other workers are eliminated. Loading and unloading requires devices which must be maintained and checked so that the work can be performed safely. Within a workplace, the common rules should be clear for all workers who are working in the area, including the subcontractors. The transferred material at construction sites is heavy and the weight of the materials also increases the risks.

The challenge is to store the materials that need to be transferred in such a way that the location is close to the final destination, but far enough away from the working and transfer area, and the stored materials should not cause any accident risks for workers.

The risks in supply chains are often linked to business risks. This study states that preventing occupational accidents also increases profitability. Thus, accident prevention should be included in risk management for supply chains. Recognising the broad range consequences of occupational accidents throughout the entire logistic chain probably creates an understanding of the importance of accident prevention. Material damages are a recognized unwanted event in logistic chains. Usually, material damages and occupational accidents are related to each other. Preventing both unwanted events increases the profitability of logistic chains.

It is widely known that fatigue is risk factor when driving in traffic. However, heavy vehicle drivers work longer working times than is legal. A common explanation for exceeding the working and driving time regulations was tight schedules. This result showed that heavy vehicle drivers were less likely to fall asleep at the wheel if they could choose the time for their breaks and if their working time met work time regulations. This gives rise to an interesting question regarding why drivers feel that they have to exceed work time regulations. The risks are known by all the parties, that is to say, the employer, the worker and the clients all know the risks involved.

Probably one answer for why heavy vehicle drivers have long working days and insufficient breaks is money. It is cheaper to have only one driver on duty than to schedule several drivers for one transport operation. Scheduling several drivers for one transport operation means that the price of transporting the materials increases. Competition between companies impacts transportation costs, which means that those companies with responsible scheduling might need to increase their prices. At any rate, the accidents are costly for the companies and add unnecessary pain for the workers. Accidents probably are rarely taken into account when pricing the transport of materials. Thus, the prevention of accidents decreases the amount of money needed for fixing the consequences of the accidents. For example, when calculating the costs of the road accidents, in addition to the injured driver, the transported material is probably also somehow damaged and the final delivery will be late, all of which affects the reliability of the transport company.

It is essential to adequately plan the material transfers both on the roads and at the construction sites. In addition to driving, the drivers have several other duties, like loading and unloading, which involve accident risks. It is important to have appropriate devices for material transfers in order to avoid unnecessary lifting or carrying of the loads, which may result in back injuries. Planning of the material transfers includes planning of the routes used while carrying the materials through the construction sites in order to keep the workers away from the routes of the vehicles.

Training for safe working methods needs to be carried out both for heavy vehicle drivers and for construction workers. In addition to know their main work, the drivers should get training in loading and unloading. The training should involve the use of devices and the idea of adopting safe working methods.

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