The increasing use of portable computing and communication devices and its impact on the health of EU workers

European Commission

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European Commission

Directorate-General for Employment, Social Affairs and Equal Opportunities

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Executive summary

Portable computing and communication devices are widely used by workers in different occupations and their use is steadily increasing.

Working with portable devices and systems differs markedly from the work with visual display units at workstations which is regulated by the European visual display units (VDU) Directive[1] and governed by a host of guidelines and recommendations within the Member States of the European Union (EU MS)[2].

What are the new and changing risks to the safety and health of the working population from the steadily growing use of portable systems and devices and their ongoing technical development?

Which problems can be identified for the employers' occupational safety and health (OSH) management and for legislation and implementation in the EU and its Member States? What scope is there to solve these problems?

Against this background, the main findings of this study are shown below.

The first part of the study gives an overview of **the technology and its use**, especially of:

- the various types of portable computing and communication systems currently in use including devices such as personal digital assistants (PDAs), laptop computers, smart phones, tablet personal computers, etc. (types of systems);
- the types of work that such computing and communication systems are used for (types of work);
- the extent to which portable systems are used by the working population – exploring how their prevalence is growing in absolute terms (extent of, increase in, use). The volume of work and types of tasks that the systems are commonly used for and the extent to which they are used (e.g. number of emails sent/received, time spent using them); how the systems permit or encourage work during free time (e.g. after office hours, at weekends and on holiday);
- the types of workers using portable systems (categories and numbers of workers) and the number and types of workers affected. While still regarded by many as 'executive toys', these systems are increasingly used by salespersons, technical support workers, delivery persons, restaurant and maintenance staff, etc.;
- how the technology behind these systems – and especially the hardware and telecommunications – is developing, and how the technology is likely to evolve in the future, highlighting the most important emerging technologies and explaining what this means for future work patterns (evolution of technologies and future use).

[1] Council Directive 90/270/EEC on the minimum safety and health requirements for work with display screen equipment.

[2] e.g.: Swedish Work Environment Authority: "Work with Display Screen Equipment"; UK: Statutory Instrument 1992 No. 2792 "The Health and Safety (Display Screen Equipment) Regulations 1992"; Estonia: Regulation No. 362 of the Government of the Republic of 15 November 2000 "Occupational health and safety requirements for work with display screen equipment"; Germany: Bildschirmarbeitsverordnung, BGI-650 (Bildschirm- und Büroarbeitsplätze – Leitfaden für die Gestaltung).

The sources of information that have been reviewed and analysed are – survey results, sales data, manufacturers' and service providers' information, published scientific research, market research, data from national authorities, and expert opinions. The aim is not to give a statistical overview, but rather to use the reliable data available to describe the situation and identify trends. However, the available data are for many issues still very limited, because most of the statistics found relate to consumer products.

Important stressors that were found are, for example, the blurring of boundaries between work and family life, the extension of the working day, difficulties in supervising mobile employees at work and the feeling that mobile employees have of being insufficiently involved in company decisions and having poorer career prospects. These stressors may cause increased stress and mental fatigue which in turn may have long-term consequences e.g. a weakening of the immune system, psychosomatic diseases, sleep disorders and cardiovascular disease.

Measures to decrease mental strain in mobile workers that use portable computing and communication devices can include the training and preparation of these employees to organize their mobile work themselves and to identify and prevent stressors that may impair health. Feedback routines for the evaluation of performance should be agreed and employees should not be forced to be available at all times. It should also be borne in mind that specific sectors, e.g. the industrial as opposed to the administrative, may differ significantly regarding the occurrence of psychosocial risks.

The **main ergonomic risks** considered are:

- manual handling problems resulting from the inevitable compromise in terms of usability in the design of portable devices, bearing in mind that they will sometimes be used in cold conditions or situations encouraging poor posture;
- repetitive movements, especially involving a pinch grip, which may induce repetitive strain injury;
- poor legibility resulting from small display screens and controls, together with problems arising from reflective glare or excessively low ambient lighting;
- excessive noise levels resulting from high volume settings to compensate for background noise;
- static and/or poor posture resulting from using the devices in an unsuitable environment;
- cognitive load resulting in accident risks, e.g. when driving or as a pedestrian crossing the road.

Using the data found, no reliable assessment of the risk factors mentioned above was possible. Instead, we have made assumptions about their impact whilst highlighting fields of interest for further research.

It would seem advisable to distinguish between different occupational categories or groups of workers. In addition to the differences in work environments for portable systems, these categories reflect differing degrees of intensity of portable systems use and of ICT (information and communication technologies) skills in most cases as well. **Since the duration and intensity of portable systems use are crucial factors particularly with regard to biomechanical workload, it is important to analyse the organization of work as well.** Of course, while variations between different occupational categories may affect the total amount of biomechanical and cognitive workload, they may also be helpful for identifying the resources available to enable the user to cope with a certain workload.

In addition, it is important to take account of future developments in technology. Since portable systems designed for communication tasks are smaller and lighter than those designed for computing tasks, they tend to reduce the biomechanical load and are more appropriate for mobile work. Likewise, there is evidently **a need for the user-centred design of mobile devices which are compatible with the cognitive load during mobile work**. Future portable systems should facilitate multitasking activities, for instance.

Mobile IT (information technology)-supported work is considered hard to design and regulate with the aid of conventional occupational safety and health approaches. This is because many aspects of work which are fixed in traditional work settings become variable within mobile IT-supported work situations. OSH principles and measures based on such factors are thus no longer applicable within this new setting. In this way, mobile IT-supported work confronts corporate **OSH management** with new challenges. Many of the factors relevant for the OSH of mobile IT-supported workers are associated with organization and processes. OSH management must, therefore, adopt an approach which will ensure compliance with the legal restrictions and OSH regulations. **It should encourage a more holistic approach in cooperation with other organizational management disciplines.** This seems to be a key factor for successfully applying occupational safety and health management in the mobile IT-supported work sector and thus for the overall health of individuals at work.

To describe the **implications for regulation and implementation**, we analysed the existing European legislation against the background of the new requirements from the field.

We present and discuss several **options for adapting existing legislation** and adopting alternative solutions for dealing with new and ongoing developments in this field.
The OSH Framework Directive covers all risks, all kinds of work and addresses the obligations without exempting any employers. The requirements are applicable to all specific aspects of work with portable devices. In this sense, there are no loopholes in existing OSH provisions.

Our analysis of the VDU Directive shows that, while it is clearly not applicable in the mobile environment in a legal sense, it can be used as a guideline for the design of portable devices, if not for how users work with them.

It is worth noting that the implementation of the VDU Directive in some EU Member States does not exclude from its application the work with portable devices at workplaces.

Three different approaches to legislation for working with portable systems can be described:

a) a new directive for working with portable systems;

b) extending and updating the VDU Directive to include work with portable systems;

c) no new or updated regulations.

In cases (b) and (c) there would be a need for guidelines for work with portable systems.

Whichever of the options proposed above is chosen, those charged with its **implementation** will be faced with the practical problem that it is impossible to effectively monitor work with portable systems in the field. The labour inspectorates must focus their controls and

enforcement on the OSH management of working with portable systems (e.g. selection of appropriate systems, risk assessment, adapted organization of prevention).

The **conclusions** drawn from the investigative part of the study are as follows:

1. The occupational use of computing and communications systems is continuing to grow in terms of:
- the number of users;
- the fields of application and activities;
- new technologies.

2. The following terminology is proposed:
- "mobile IT-supported work";
- "mobile e-Worker".

This is because these two aspects combined – mobility and the use of portable IT – are the characteristic features.

3. Since activities in the various fields of application differ greatly in some respects and the distinction between blue- and white-collar activities is becoming blurred, categorization on the basis of the characteristics of the particular activity makes more sense for the identification of risks and taking preventive measures.

4. The health risks due to poor or maladapted ergonomics and psychosocial stress are varied and considerable. They vary from acute dangers (accident risk, e.g. from the use of portable devices when driving) to the latent risks of chronic physical and mental illness. These are the result not only of the direct use of the devices but also, and more importantly, of the circumstances in which devices are used. The first standards, recommendations and principles can already be defined on the basis of the existing findings.

5. There is a lack of representative and specific studies on mobile IT-supported work. These are necessary so that evidence-based guidelines can be drafted and specific, targeted measures defined.

6. Employers can and must shoulder their responsibility for the safety and health of their mobile e-workers even when they work away from their normal base. OSH management practice must therefore be adapted accordingly. This includes risk assessment, the availability of suitable equipment and systems, technical and personal support, training employees to use the systems in a healthy way and a new health protection culture. Employers, and particularly small and medium-sized enterprises (SMEs), as well as manufacturers of devices and providers of IT services, need standards and generally accepted recommendations.

7. The OSH Framework Directive covers all occupational risks including all aspects of mobile IT-supported work in general. The VDU Directive is not applicable from the legal point of view, but many of its provisions are applicable in practice to portable devices and particularly the ergonomic requirements. Serving as the state of the art, these should also form the basis for possible "standards" for portable devices for occupational use.

8. There are three options for future OSH management:

- a new directive;
- modification of the VDU Directive and extension of its scope to cover mobile IT-supported work;
- no new or modified directive, but the drafting of guidelines and "standards".

The last option would appear to be the best way of satisfying the needs of OSH in the mobile IT-supported work sector in the light of the speed of technological progress.

9. The most effective way to achieve compliance is for OSH authorities to concentrate on indirect monitoring by inspecting the way work is organized in companies. They should participate in the drafting of generally accepted evidence-based OSH management "standards" and guidelines and in their dissemination.

10. OSH management for mobile IT-supported work should facilitate a holistic approach in cooperation with other organisational management disciplines. This is the key factor in successfully ensuring occupational safety and health in this new field.

Introduction

Portable computing and communication devices are widely used by workers from different occupations and their use is steadily increasing.

The risks associated with working with portable devices and systems, for which at present no guidelines exist, differ considerably from those associated with working with visual display units at workstations. The latter are covered by the European VDU Directive and governed by a host of guidelines and recommendations within the EU Member States.

In the light of the above, the study addresses the following issues:

- To what extent are mobile communication devices used by the working population – how is such use growing in absolute terms and which types of workers are using them?

- How is the technology behind these devices – hardware and telecommunications – developing, and how is the technology likely to evolve in the future?

- Description of the possible hazards arising from the use of portable computing and communication devices and the risks to workers in terms of ill health and accidents. We also consider how the nature and extent of these risks will change in the future in the light of likely developments in technology and its use.

- The implications of the use and development of mobile communication and computing devices for occupational health and safety management and for legislation and implementation in the context of European law concerning health and safety at work.

- The scope is limited to work carried out in locations and environments that are impossible or difficult for the employer to control.

I Methodology

Because of the limited time scale, the study was designed as an analysis of the literature and other available information sources such as market research, survey results and data from national authorities.

One of the findings was that there is a lack of specific research and field studies on the psychosocial and ergonomic risks of using portable computing and communication devices. Nonetheless, we were able to find a host of studies whose results could be applied to the issues covered by this project. In the ergonomics sector in particular, we made use of our own published research on input devices (keyboards, mouses etc.) for the study.

Nevertheless, it has to be stated that there is a strong need for representative field studies devoted to the specific health and safety problems and issues arising from the widespread occupational use of portable computing, communication and information systems. These should look individually at the various tasks performed or supported by those systems (see chapter II "Overview of the technology and its use").

External expert opinions and the views of national authorities were obtained in interviews with experts from European OSH institutes, universities and trade unions. When searching for experts we were faced with the problem that there is a lack of experience in this field of study among OSH experts.

A workshop was held with 14 participants from 3 countries and the European Commission in the 4th quarter of the project to present and discuss the preliminary results and to draw conclusions both from the experts' views and also from the European perspective.

The preliminary results from the different parts of the study (technology and its use, psychosocial and ergonomic risk factors) were presented and discussed. Work groups looked more closely at the implications for OSH management, regulation and implementation.

The results of the workshop are reported in the relevant sections and in the final discussion and conclusions of this report.

II Overview of the technology and its use

Summary

This chapter covers:
The various types of portable computing and communication systems currently in use, such as personal digital assistants (PDAs), laptop computers, smart phones, tablet personal computers (PCs), etc. (types of systems).

- Types of work that such computing and communication systems are used for (types of work).
- The extent to which portable systems are used among the working population – exploring both how their prevalence is growing in absolute terms (extent of, and increase in, use). The volume of work and types of tasks that the systems are commonly used for and the extent to which they are used (e.g. number of emails sent/received, time spent using them); how the systems permit or encourage work during private time (e.g. after office hours, on weekends and during holidays).
- The types of workers using portable systems (categories and numbers of workers) and the number and types of workers affected. While still regarded by many as 'executive toys', these systems are increasingly used by sales persons, technical support, delivery, restaurant and maintenance staff, etc.
- How the technology which enables the use of these systems – especially the hardware and telecommunications – is developing, and how the technology is likely to evolve in the future, highlighting the most important emerging technologies and explaining what this means for future work patterns (evolution of technologies and future use).

The study describes the sources of information that are reviewed and analysed – e.g. survey results, sales figures, manufacturers' or service providers' information, published scientific research, market research, data from national authorities and expert opinions. The aim is not to give a statistical overview, but rather to use the reliable data that is available to describe the situation and identify trends. For many issues the available data is still very limited. Most of the statistics found relate to consumer products.

This study does not focus on long-term telework, such as working from home or from a client's premises, as its scope is limited to work carried out in locations and environments which are impossible or difficult for the employer to control.

It is increasingly acknowledged that networked work environments, which make extensive use of ICT for interconnecting workplaces across space and time, often by using portable systems, play a significant role in economic competitiveness (Gareis 2006). Therefore the impact on occupational safety and health in Europe of the increasing use of portable systems is of great interest.

Introduction

Physically mobile workers (temporarily) using ICT systems[3] with high intensity to support their multi-locational or mobile work are called **mobile eWorkers**. In most cases these mobile eWorkers use portable systems for computing and communication tasks. By "portable computing and communication devices" (portable systems) [**PSs**] we understand **portable computer systems designed for deployment** on the move, (temporarily) connected to an ICT network for communication or data transfer tasks.

PSs may be independent systems or embedded systems. This study covers neither embedded systems nor telecommuting (long-term telework) because in such cases PSs are, or can be, used as stationary systems and such use does not differ from traditional office work.

With portability and styling as high priorities, ergonomics often takes a back seat in the design of PSs. Furthermore, the devices are likely to be used in environments which – from a health and safety perspective – are far from ideal. Locations such as the car, the train, or standing in the street may be convenient, but they are a far cry from a well-designed office environment.

The increasing use of PSs means that more people are working outside the office and are doing so for longer periods. As a consequence, workers experience a blurring of work and private life as they are expected to be available out of office hours, during weekends, and on holidays. This blurring is aggravated by the fact that many systems are often also used for making private arrangements, so that the traditional separation of work and private life is made even more difficult. These factors have significant psychosocial implications as a result of the intensification of work and increased pressure, combined with growing isolation.

Use of PSs in an occupational environment by mobile workers can be defined as **ICT-enabled multilocational work** (Vartiainen, Matti (5) 2008). Little statistical data exists about the actual extent and structure of this work and there is only a limited understanding of which workers are involved in these activities. The database from a recent, representative EU-wide survey (SIBIS (SIBIS 2003/2003)) can be used to explore in more depth the key characteristics of mobile eWorkers.

This document gives an overview of portable computing and communication systems (PSs) and their use by mobile eWorkers and mobile workers using PSs occasionally, the evolution of technologies in this field, and their foreseeable future use (task 1 of the study).

[3] ICT = information and communication technologies.

1. Definitions

The following definitions are not presented in alphabetic order but grouped in related themes for ease of understanding.

eWork is work using company computer systems. eWork is a synonym for **ICT-supported work**.

Mobile eWork (mobile ICT-supported work) is used to describe all kinds of high-intensity mobile work and work arrangements at the individual level carried out outside the home and the main office, using ICT for online connections to the Internet and/or to company computer systems (mobile computer-mediated work) (Andriessen/Vartiainen (eds.) 2006). Such work takes place while workers are moving or at a certain destination, wherever it suits their work activities, tasks, business schedule, and/or lifestyle (Vartiainen 2007). Mobile eWork is related to the possibility of a person moving and executing tasks anywhere and at any time, with the help of wired and wireless technologies and in a flexible manner (Andriessen/Vartiainen 2006). Mobile eWork is done in ever changing situations with a need to collaborate with other workers and to be connected to shared resources in order to achieve common goals (Corso 2006). Mobile eWork can be classified by degree of physical mobility, level of routine, type of data exchange, and degree of interaction (Vartiainen (2) Andriessen 2006).

A **mobile eWorker** is a person who works at least ten hours per week away from home and from the main place of work and uses online computer connections when doing so (from: Collaboration@Work, "The 2003 report on new working environments and practices", http://europa.eu.int/information_society/topics/ework/information/. This report uses the traditional term "teleworker").

Micro-mobility of a worker is in-house and on-site mobility (Vartiainen (4) 2007), perhaps also including nearby buildings and areas (Andriessen/Vatiainen (eds.) 2006).

Multi-mobility is regular movement between many different locations (Andriessen/Vatiainen (eds.) 2006).

Full mobility is constant movement between different sites (Andriessen/Vatiainen (eds.) 2006).

Multi-locational eWork is eWork carried out at a number of different, often fixed, locations, one of which may be the home (BISER 2004).

An **instant office** is a workplace instantly created and occupied temporarily by the worker in a location that is not primarily designed for office work[4].

Work-life balance is used to describe the balance between an individual's work and personal life (family life and leisure)[5]. The determinants of work-life balance are located both at work and in the home and in an individual's personal characteristics (including age, gender, stage

[4] Van Meel, J. "The European office – office design and national context".
[5] http://en.wikipedia.org/wiki/Work-life_balance

of career, ambition, work involvement, level of energy, capacity for coping with competing demands).

The specific characteristics of mobile eWork which can impact negatively on those involved include information overload, short response times, availability, pace of change (Richter 2006), increased access hours, reduced autonomy, less freedom, pressure to work, multi-tasking, and thinking time viewed as "non-value-added". On the positive side, meWork can allow some flexibility to redress the impact of travelling (Shaffers (2) 2006).

A **portable system** [PS] is a personal, small and lightweight ICT tool (hardware product), designed to be used "on the go"/"on the move", and that is temporarily independent of an external electric power supply.[6] [7] A PS can be portable, wearable or at least easy to pack up and move (Wilson 2006). A PS can contribute to making a normally stationary eWork practice mobile (Johansson 2006). In the context of this study PSs are regarded as (temporarily) connected to ICT networks for communication or data transfer tasks.

A **wearable computer** is a ruggedized system subsumed into the personal space of a user, is always with the user and controlled by the user hands-free, is proactive, always on, always accessible, often uses sensors for context- or location-awareness, and is connected to an ICT network[8].

[6] Often portable systems are called mobile devices; this term is not used in this study because ICT systems typically are not themselves mobile and the term 'device' also is used for technical objects that cannot act alone or independently of other components.

[7] The core toolset of meWorkers consists of a laptop computer and a mobile phone (Nieminen, Mannonen, Petri 2007).

[8] Wearable computer definition adapted from Steve Mann's keynote address entitled "WEARABLE COMPUTING as means for PERSONAL EMPOWERMENT" presented at the 1998 International Conference on Wearable Computing ICWC-98, Fairfax VA, May 1998, and from the definition given by Rachuy, Carsten and Warden, Tobias in "Probleme und Chancen der Benutzerschnittstellen bei Wearable Computern", University of Bremen, artec-paper Nr. 118, October 2004.

2. Status quo analysis

2.1 Description of portable computing and communication systems

2.1.1 Types

In this chapter various types of PSs currently in use, such as personal digital assistants (PDAs), laptop computers, smart phones, tablet PCs, etc., are described in order to give an overview of the state of the art in this field. This overview starts with first handheld computers and ends with newer market products such as the so-called **Mobile Internet Devices or eBook readers**.

The descriptions of specific types of PSs are mostly taken from the Internet encyclopaedia Wikipedia (Wikipedia)[9], though a few are from manufacturers' own websites[10].

In an English language environment a distinction is made between mobile devices and desktop computers[11]. "Device" in the computing and electronics context may refer to computer hardware, a peripheral device, device file, information appliance, display device, electronic component or integrated circuit[12]. A peripheral device is any device attached to a computer which expands its functionality. According to these definitions portable computing and communication "devices" are portable computer systems [PSs].

Typically such PSs do not always act alone when used by mobile eWorkers, because they are part of a solution that needs a communication network. In situations where PSs are used for electronic communication or data transfer, they can correctly be named 'devices'. This study deals with **systems** that are designed for computing and communication purposes; but these **are independent** portable **computers also used for communication** tasks, and therefore (sometimes) connected to a communication network. In order to employ an already well defined word, in this study we will avoid using the word "device" and instead use the term "system" (portable computer system). Whenever such systems are not able to operate without any local or wide-area network, the word "device" will be the correct one.

Many types of PSs have been introduced since the 1990s. These include:

- Personal digital assistant (PDA),
- Enterprise digital assistant (EDA),
- Smartphone,
- Wearable computer,[13]
- PDT,[14]
- UMPC,[15] [16]

[9] Wikipedia content can be copied, modified, and redistributed *so long as* the new version grants the same freedoms to others and acknowledges the authors of the Wikipedia articles used (a direct link back to the article is generally thought to satisfy the attribution requirement). More information on reuse of Wikipedia material can be found at http://en.wikipedia.org/wiki/Wikipedia:Copyrights#Reusers.27_rights_and_obligations.

[10] http://www.microsoft.com/windowsmobile/components/devices/

[11] http://en.wikipedia.org/wiki/Mobile_web

[12] http://en.wikipedia.org/wiki/Device

[13] Research is going on in the field of wearable computers, see chapter "Technology Development".

[14] Portable data terminal.

[15] Ultra-mobile personal computer.

[16] http://www.intel.com/products/mid/downloads/umpc2006.pdf

- Calculator,[17]
- Laptop
- eBook reader,
- MID,[18]
- etc.

2.1.2 Functionality, characteristics and ergonomic features

The functionality, characteristics and ergonomic aspects of a sample of PSs currently in use will be described here in order to give an overview of the current situation in this field.

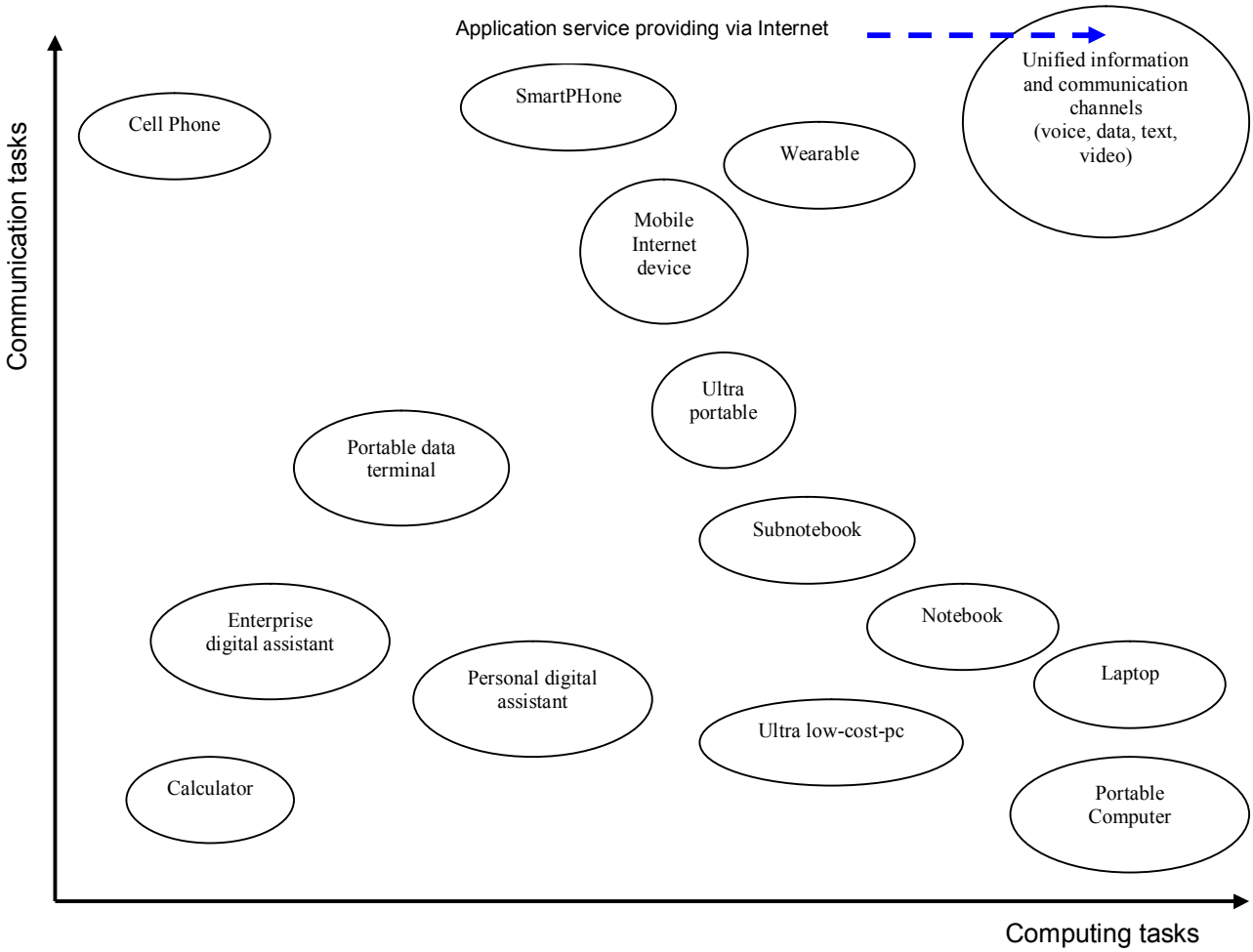
PSs can be classified by the application for which they have been designed, as they are mainly intended either for **communication** or for **computing tasks**. Systems designed for communication tasks are more miniaturized and lighter than those designed for computing tasks and therefore are more appropriate for supporting mobile work.

For this reason, all current types of PSs may converge in designs which make use of computing facilities via Internet or other networks (application service providing (ASP)), leaving PSs for communication tasks only. Computing tasks would then be run on servers, so that PSs would only be used for inputting tasks and displaying the results.

The technology seems to be evolving in the direction of unified communication and information channels that allow communication in multimedia mode (voice, data, text, and video) together with related services, such as (instant) **teleconferencing** or **asynchronous communication**.

[17] A calculator is a system that is not used for communication purposes and therefore is not further described in this study.
[18] Mobile Internet device.

Figure 1: Characteristics of portable ICT tools



While at first glance some PSs seem adequate for office or permanent use over several hours, further scrutiny shows that, while their functionality is in principle the same as that of non-portable systems, their characteristics and ergonomic aspects make them inappropriate for permanent occupational use.

On the other hand, PSs may not need to meet the provisions of the Directive because they are designed only for occasional use and may be adapted for longer term use by means of accessories. For instance, where necessary or advisable, an external display and a separate keyboard are supported by a standard VGA (Video Graphic Array) connector and USB ports.

Given that PSs are mostly purpose- or custom-built and assuming that only appropriate systems are used, **the impact on occupational safety and health of the increasing use of PSs can only be fully evaluated with reference to the purpose and user group of specific systems**.

From the point of view of users, all PSs have been designed to be used “on the go”/“on the move”. For this reason, they have been optimized in terms of size and weight and with regard to environmental conditions but with little attention being paid to the impact of the design on occupational safety and health. Moreover, because of their potentially universal application, sometimes systems designed for mobile use are used in situations and for applications for which they were not intended.

Portable systems have been designed to be portable, and their designs therefore conflict with some usability and ergonomic criteria. If these criteria are incompatible with portability, this conflict may prove irresolvable.

The following photograph confirms our personal experience that the miniaturisation of PSs can have a positive impact on occupational health and safety.

Photograph 1: Person carrying a laptop

Source: Lucy Dunne, *Adaptive Information Cluster, University College Dublin,* Jane McCann, *University of Wales, Newport,*Sirpa Mörsky, *HAMK, University of Applied Sciences, Hämeenlinna: "Humans – A Tutorial" (slide show).*

The function of PSs is to support computing and communication activities; they are characterized by their design for mobile users, and from an ergonomic point of view they are not intended for constant use. Some PSs are designed for outdoor use and therefore can be used in bad weather or other adverse environmental conditions.

2.2 Description of work with portable systems

2.2.1 Types of work using portable systems

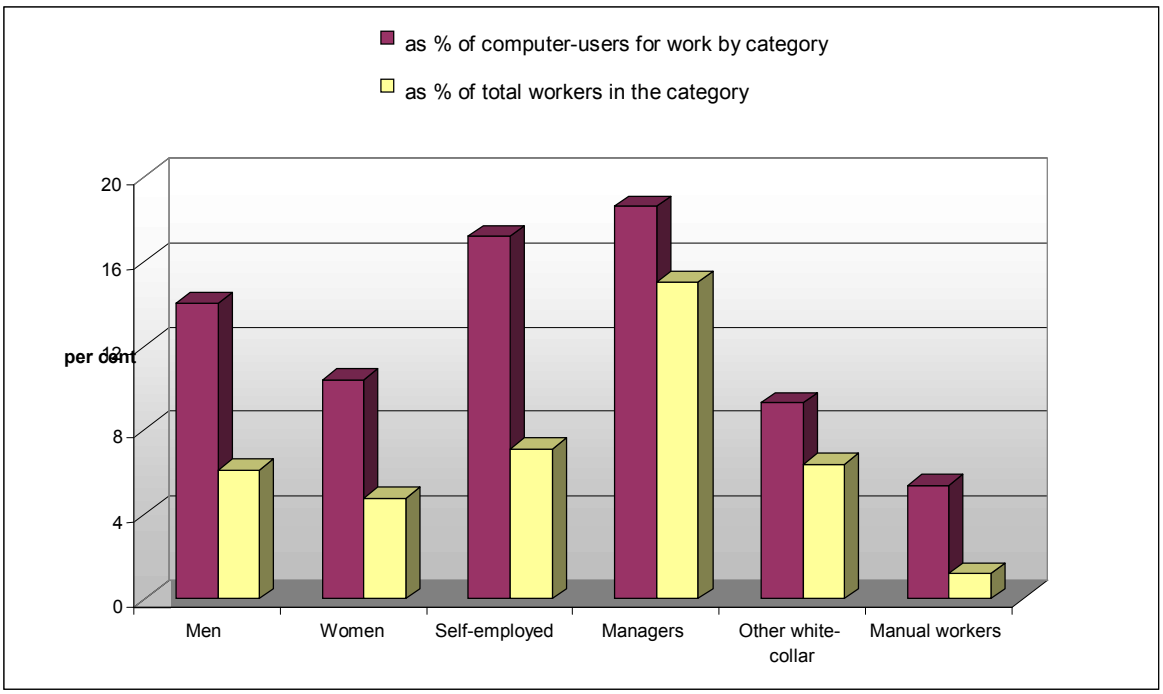
This chapter identifies the **types of work** in which PSs are deployed.
The following aspects are of relevance for an analysis of the types of work in which PSs are used:

- The target group of ICT solutions with a PS as end-user tool;
- The character and form of occupational use;
- Typical activities, tasks and jobs supported by PSs (scenarios, descriptions of usage);
- The field and range of application/functions of ICT solutions using PSs as end-user tools;
- Usability;
- The distinction between office work – including management jobs – and other work, such as factory or maintenance work.

The types of work in which PSs are used can be characterized as those in which workers are doing mobile computing "on the go"/"on the move". This does not mean that these workers are travelling. On the contrary, PSs are often used by workers that are only mobile on their employer's premises or on campus (micro-mobility). Regardless of occupation and category of worker (white- or blue-collar worker), PSs are mostly used for information and communication tasks. This is the function and aim of computer systems and telecommunication networks. The differences originate from different solutions, applications and services, and have little to do with the main characteristics of PSs.

From figure 2 we can see that in 2001 non-office workers (manual workers) did not use computers as much as office workers. Managers had a very high rate of computer use (eWork 2001 and eWork 2002 [2001/2002]). It can be assumed that this category of worker also uses PSs more often than other workers.

Figure 2: Teleworkers by gender and category of occupation; 2001

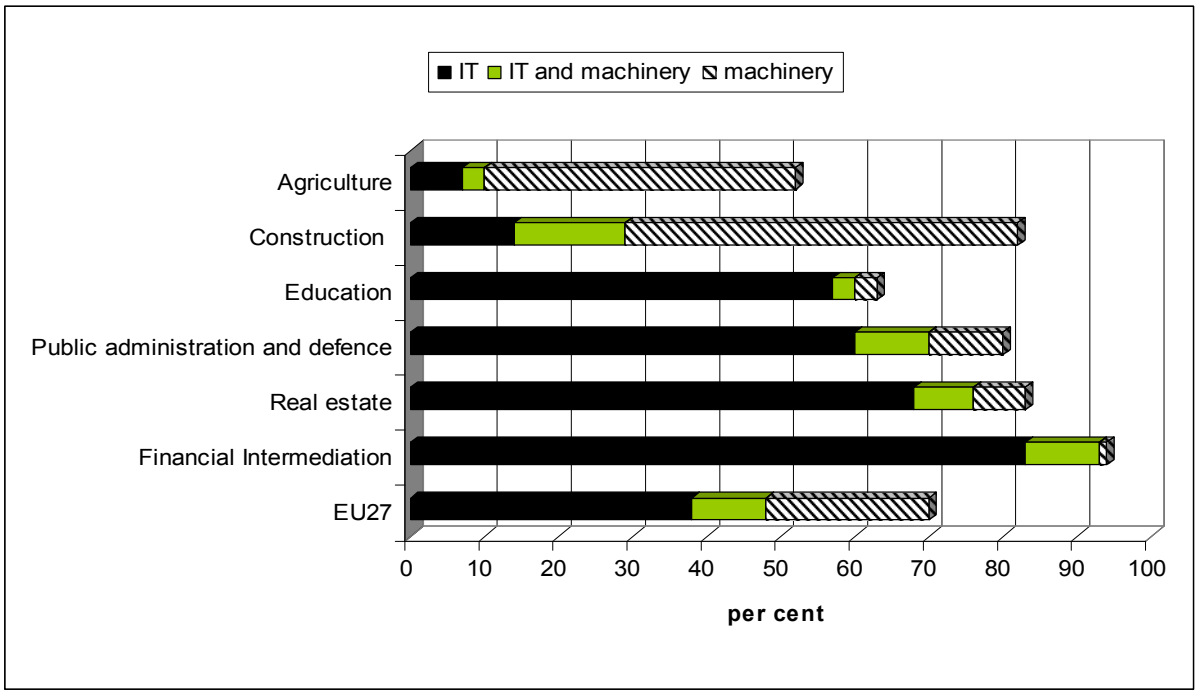


Source: Eurobarometer, November 2000.

An analysis of the possible fields of occupation, using the typical classification (development, production, sales, assistance, organizational support, and social services) shows that production activities (manufacturing, building, installation, etc.) are not ICT activities, while assistance tasks (operating, controlling, monitoring, etc.) can be supported by ICT. Typical activities with ICT support are planning, design, programme development, information, publishing, or promotion (sales), education, entertainment and care (social services). However, the main field of ICT use is activities and tasks related to organizational support (organizing, managing, writing, calculating, drawing and communicating). It is important to understand that regardless of the occupation (profession) or job, typical work using PSs is characterised by activities that can be, and are, supported by ICT. This will be shown in more detail in Chapter 2.3.3 "Typical activities and tasks". Whether people are working, for example, in customs control, facility services, maintenance services, home care or project management, most types of mobile work (including micro-mobility) can be supported in some way by using PSs. Therefore it is difficult to categorize the use of PSs by type of work or by profession. Generally, much less ICT support is possible in production work than in service

work. One group of workers in all sectors that use ICT to a very high degree are the so-called knowledge workers, who typically use PSs while "on the go". The following diagram shows the importance of ICT use by sector. The rates of ICT use are very high in the sectors of financial intermediation, real estate, public administration and education, which again shows that ICT is used for information and communication purposes. Those workers whose work implies a significant use of PC and Internet are classified as "IT" workers (37% of EU workers).

Figure 3: Use of ICT by sector



Source: Excerpt from European survey on working conditions 2007.

There are substantial differences in the use of technologies in the different occupational groups[19]. Professionals, clerical workers, technicians and managers use IT most widely, in all cases above 50%. At the other end of the spectrum are skilled workers and machine operators (who use machine technologies in more than 60% of cases). Agricultural workers, unskilled workers and service workers show low levels of use of both types of technology (with more than 50% of workers not making any substantial use of technology at all).

A deeper analysis of types of work using portable systems requires a large number of different classifications. The following classification method has been used in the Fourth European Working Conditions Survey[20]:

- Gender and age (15 – 29, 30 – 49, 50+);
- Education – primary or lower, lower secondary, upper secondary, post secondary, tertiary, postgraduate;
- Occupation – senior managers, professionals, technicians, clerical workers, service and sales workers, agricultural and fishery workers, skilled workers, machine operators, unskilled workers;
- Sector – agriculture and fishing, manufacturing, electricity/gas/water, construction, wholesale and retail trade, hotels and restaurants, transport and communication, financial

[19] See: European survey on working conditions 2007.
[20] European survey on working conditions 2007, Table 5.1

intermediation, real estate, public administration and defence, education, health, other services;
- Technology at work – IT, IT and machinery, machinery, little or no technology.

2.2.2 The work environment of mobile eWorkers

Some aspects of the usual work environment of mobile eWorkers will be presented in this chapter.

The physical workplace can be described as a combination of:
- Work settings, i.e. furniture + ICT equipment;
- Space, i.e. office, factory, meeting room, project area, café, airplane, forest, car;
- Environment, i.e. office building, city district, street, airport, train, bus, natural environment, home;
- Conditions, i.e. time, weather, sunlight, temperature and other environmental influences.

Additionally, the work environment can be described as:
- The physical workplace,
- A virtual space (established by ICT)
- A social space (established by other people).

The MOSAIC consortium[21] (Shaffers (1) (eds.)), for example, has analysed the dimensions of place and time in eWork, highlighting the fact that the work environment of mobile eWorkers is a very complex research subject. Those interested in learning more will find a wealth of fascinating results from this research on the AMI@Work website[22].

PSs are mostly used to support multi-locational or mobile eWork outside the traditional workplace. The term "multi-locational work" implies that persons spend working time at more than one location as it suits their work tasks, business schedule and lifestyle (BISHER 2004). The concept of geographically mobile eWork implies that means of production, staff, objects of work and cooperation partners can be geographically separated from one another.

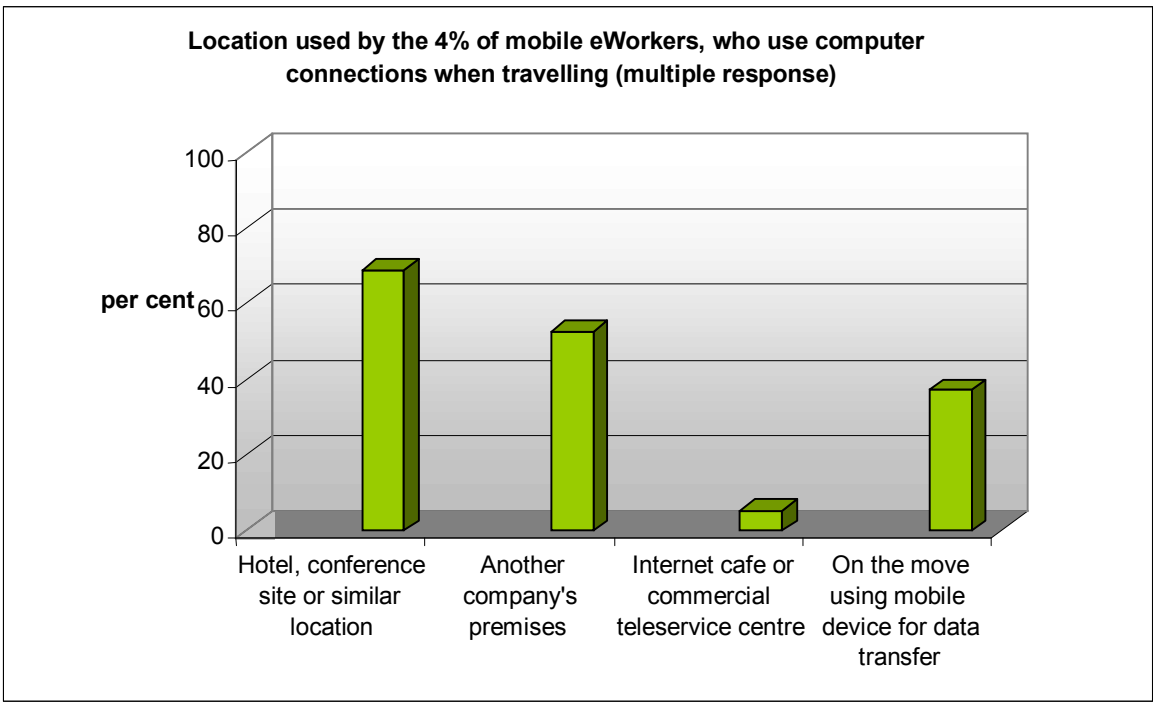
Furthermore, the organisational and technological changes necessary for relocating eWork result in new ways of work organisation that in turn make it easier to relocate further work. The place of work of knowledge workers typically is a hotel, conference site or similar location, or another company's premises. The main purposes of mobile eWorkers using online connections is sending and reading e-mails (92.4%) – less for outgoing than for incoming communication – but about three quarters also browse the Internet and connect to their company's internal computer systems. However, 37% of EU15 mobile eWorkers use mobile systems for data transfer on the move.[23] Potential access points are teleservice centres such as Internet cafés, which offer mobile eWorkers a temporary workplace equipped with PC, Internet access, printer, fax etc. Such service providers are emerging at the nodes of international traffic. They may contribute to making mobile work attractive, offering a working environment like an office. However, currently only 5.4 % of all mobile eWorkers make use of teleservice centres. (Gareis 2006)

[21] MOSAIC (Mobile Worker Support Environments) is a specific campaign, funded by the European Commission under the IST 6th Framework Programme; its key objective is to accelerate innovation in mobile worker support environments by shaping future research and innovation activities in Europe, see http://www.ami-communities.eu/wiki/MOSAIC.

[22] http://www.ami-communities.eu/wiki/communities

[23] Base: All persons employed (N=5,100); weighted by EU15 population. Data source: SIBIS2002, GPS.

Figure 4: Locations where mobile eWorkers use Internet while travelling



Source: Gareis, 2006.

The Fourth European Working Conditions Survey (European Survey on Working Conditions 2007) classifies workers by a single composite indicator of the usual place of work according to their answers in one of the following eight categories (see table 1).

Table 1: Usual place of work

Place of work	Percentage of EU workers (%)
In company	50
On company premises and outside	12
Only outside	10
Outside and from home	2
Only from home	2
At company and from home	6
A significant amount of time in all locations	5
Other	13

Source: European survey on working conditions 2007.

From table 2 we can see that about 7% of those accessing the Internet use a laptop to do so. About 8% use a mobile phone for Internet access, and about 1% a handheld/pocket PC (EU15, Eurobarometer, November 2002). The statistics for consumer products indicate an upward trend here. It can be assumed that most of this usage is taking place during working time, because laptops and pocket PCs are typical tools for mobile eWorkers. Internet access via mobile phone will also mostly be used for work purposes, because Internet access for

private reasons is cheaper and much more convenient from a home landline. From these figures, together with statistics about how many people access the Internet, it can be estimated how many mobile eWorkers are accessing the Internet with PSs.

Table 2: Place of use of Internet and mobile access

	EU-15	BE	DK	DE	EL	ES	FR	IE	IT	LU	NL	AT	PT	FL	SE	UK
Proportion of persons using Internet (%)																
At home	71	71	83	72	50	61	64	74	68	84	87	77	64	74	84	74
At work	43	47	50	37	26	36	44	42	40	44	50	44	42	50	57	51
At a friend's or relative's home	33	33	15	40	21	21	40	30	20	27	32	17	20	22	26	41
At school, college, university	19	25	15	17	24	21	20	23	15	17	18	13	24	23	19	24
From a public access point	13	14	8	11	4	10	15	19	7	9	14	4	12	17	12	18
At an Internet cafe	9	6	3	11	20	16	6	14	5	8	9	4	4	4	5	9
With a mobile phone	8	6	1	14	1	2	5	7	2	7	7	2	4	3	6	11
With a laptop	7	9	2	6	2	2	10	10	4	8	6	4	4	4	10	14
With a handheld /pocket PC	1	1	0	1	0	0	1	2	0	1	1	1	0	0	2	3
Elsewhere	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0

Source: Flash Eurobarometer 135, November 2002; Information society statistics, Data 1997 – 2002, THEME 4: Industry, trade and service, 2003 edition (Information Society Statistics Pocketbook 2003), European Communities, Office for Official Publications of the European Communities, Luxembourg.

From the following tables – the latest Eurostat statistics on Internet use – we can see the individual Internet use by country. For this study the table showing the percentage of individuals who accessed the Internet at places other than work or home is of most interest.

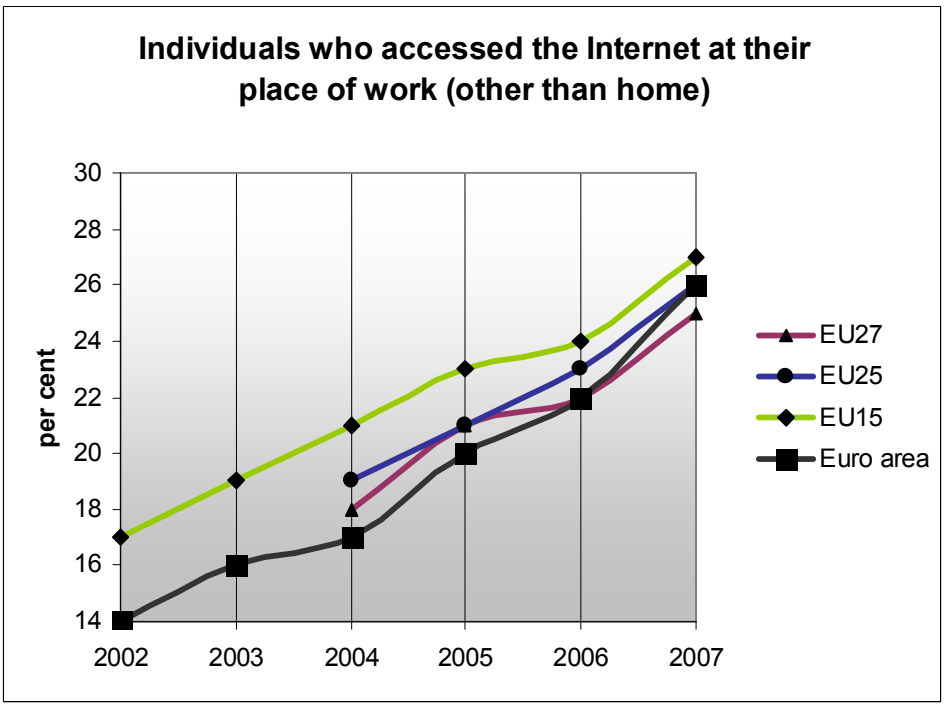
Table 3: Percentage of individuals who accessed the Internet at their place of work (other than home) in the last 3 months

	2002	2003	2004	2005	2006	2007
EU27	:	:	18	21	22	25
EU25	:	:	19	21	23	26
EU15	17	19	21	23	24	27
Euro area	14	16	17	20	22	26
Belgium	:	:	:	18	21	23
Bulgaria	:	:	6	:	10	12
Czech Republic	:	13	14	14	20	21
Denmark	32	35	41	37	46	43
Germany	17	16	18	20	27	30
Estonia	:	:	20	20	28	27
Ireland	:	13	15	17	23	22
Greece	6	7	9	10	12	15
Spain	9	16	18	20	22	23
France	:	:	:	.	18	25
Italy	14	14	15	16	17	18
Cyprus	:	:	14	14	17	20
Latvia	:	:	17	18	22	22
Lithuania	:	10	12	15	17	19

	2002	2003	2004	2005	2006	2007
Luxembourg	21	26	27	26	32	34
Hungary	:	:	10	17	19	21
Malta	:	:	:	16	14	18
Netherlands	:	30	:	36	39	43
Austria	21	19	24	25	29	32
Poland	:	:	9	11	13	14
Portugal	9	13	15	15	16	17
Romania	:	:	4	:	7	8
Slovenia	:	:	20	23	28	28
Slovakia	:	:	26	27	26	29
Finland	31	35	37	38	39	39
Sweden	37	36	37	40	38	42
United Kingdom	26	27	29	31	30	32
Macedonia, the former Yugoslav Republic of	:	:	5	:	4	:
Turkey	:	:	5	6	:	:
Iceland	:	38	41	47	49	56
Norway	:	40	41	47	47	48

Source: Eurostat, 2008.

Figure 5: Individuals who accessed the Internet at their place of work (other than home) in EU27, EU25, EU15, Euro area



Source: Eurostat, 2008.

The work environment of mobile eWorkers is primarily – but not solely – described by the place of work. For the purposes of this study secondary and tertiary workplaces are of some interest. Examples are telework/business office, guest office, and home (if not the main workplace), which are regularly work places, and instant offices in a hotel, café, Internet café or outdoors and moving workplaces in public transport vehicles, etc.

Besides the place of work, the work environment of mobile eWorkers can be influenced by the time of work (especially in a leisure time environment) and by environmental conditions such as temperature and weather, especially in the case of outdoor work.

Instant offices can be furnished with portable items such as special bags with a hard cover (of reinforced plastic) to place a laptop on or suitcases with a fold-out tray, table or desk. A portable laptop table, for example, consists of a table top and adjustable leg.

Photograph 2: A portable laptop table

The physical workplace of mobile eWorkers can be described as a combination of:

- Deficient work settings, i.e. missing furniture + PSs designed for short term use;
- Spaces such as vacant offices, meeting rooms, cafés, airplanes, cars, public transport vehicles, outdoors;
- Environments such as streets, airports, natural environments, family home;
- Detrimental conditions such as work in free time, bad weather, too much sunlight, low or high temperatures and other less than favourable environmental influences;
- ICT support different from that at a permanent work place;
- Lack of informal social contacts with colleagues and face-to-face meetings.

It is apparent that the work environment of mobile eWorkers is much worse than that of stationary workers, both in terms of "real" and "virtual" work settings, space and environmental conditions and in terms of mental/social space requirements. Furthermore, in the majority of cases this working environment changes during a work day and cannot be controlled by the employer.

2.3 Survey of the use of portable systems among the working population

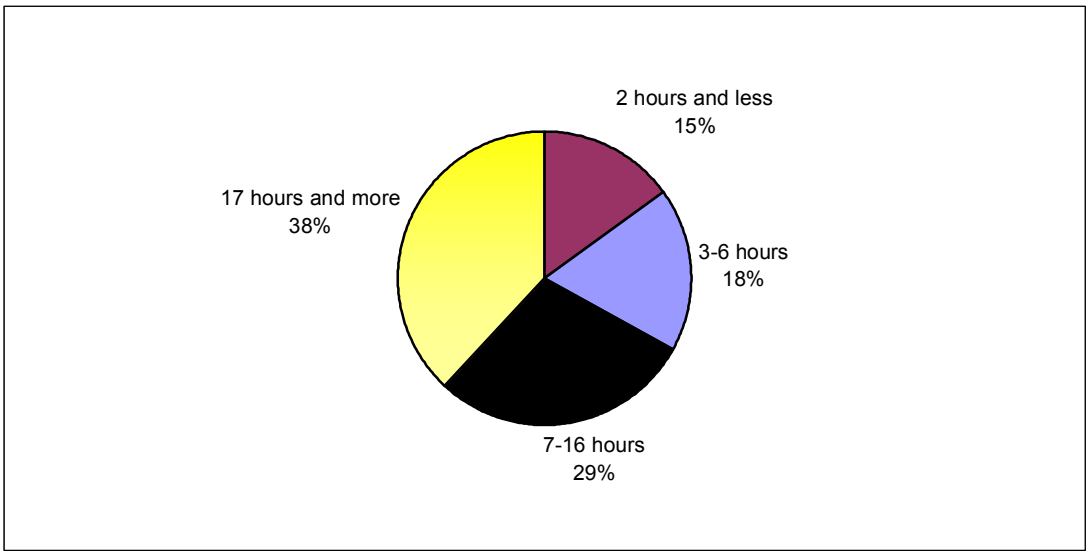
2.3.1 Extent of, and increase in, use

Mobile eWork can be defined as high-intensity mobile work in the course of which an online connection to the Internet and/or to company computer systems is used.

According to the data from SIBIS (SIBIS 2002/2003), 28% of EU15 workers spent some paid working time doing mobile work in 2002. The number of high intensity mobile workers[24] was roughly half of this (15%), and 4% of the EU15 work force in 2002 were meWorkers (Gareis 2006).

67% of these mobile workers spent more than 7 hours per day (unweighted average) on the move, while 38% were on the move for more than 17 hours. It seems obvious that for this group of workers PSs are of high importance, as PSs give them the opportunity to do eWork during travel time and to be reachable by their colleagues and/or customers.

Figure 6: Time spent on the move by mobile workers[25] [26]



Source: SIBIS General Population Survey, 2002.

As we can find from the Fourth European Working Conditions Survey (European Survey of Working Conditions 2007), a considerable proportion of people (almost 30%) never or almost never work at company's premises. Around 15% works always or almost always outside their home or company's premises. Twice as many do so at least a quarter of the time.

The percentage of mobile eWorkers among the total EU15 workforce grew from 1.5% to 4% in the course of only three years (1999-2002) (Gareis 2006) with a trend towards further growth (the share in Finland had already reached 6.2%). There is much evidence that mobile eWork will continue to increase. According to the Working Life Barometer 2002 (Ministry of Labour, Finland) almost 40% of wage and salary earners carried out work tasks in their leisure time by means of a connection to their employer via mobile phone or ICT network (Gareis 2006).

Figure 7 shows that about 38% of EU15 workers are tele-cooperating and about 12% are doing multi-locational eWork[27]:

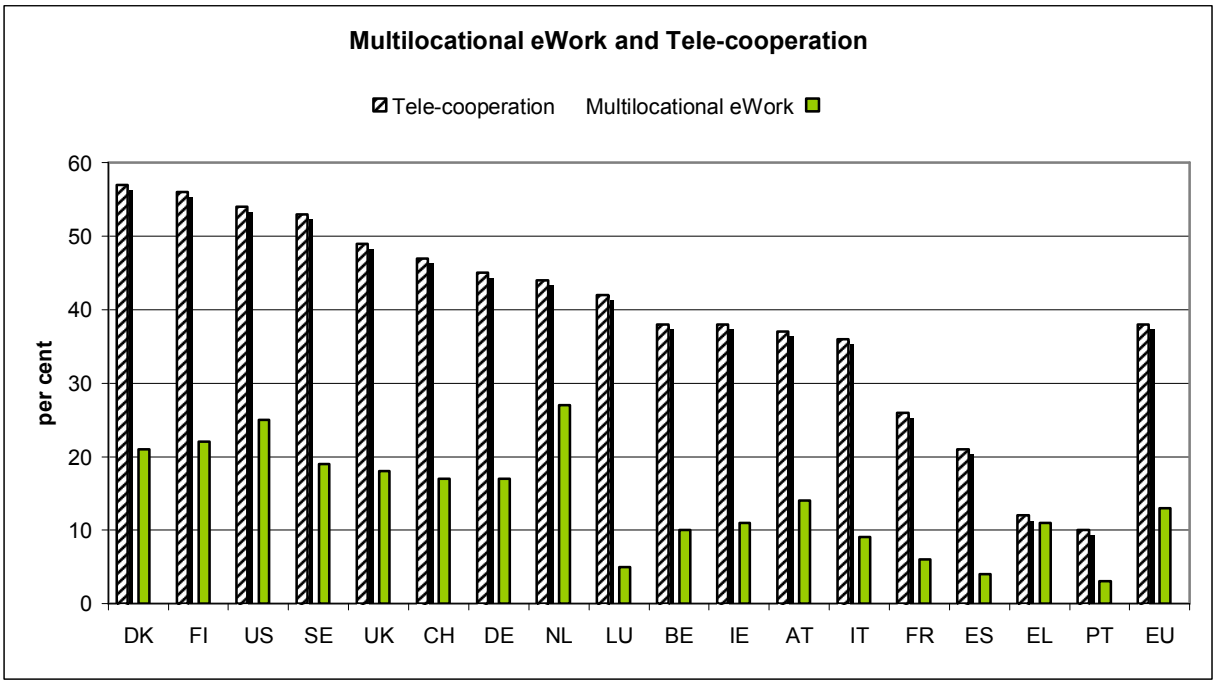
[24] High-intensity mobile workers are those who do so for 10 hours or more per week.

[25] Unweighted average for EU15, CH and USA. Base: All mobile workers (n = 1277). (Gareis 2006). The number of hours has been rounded to whole numbers.

[26] For instance in 2002 15.4 % of EU15 workers were high intensity mobile workers and about 6 % of all workers average 17 hours and more on the move. Base: All persons employed (N=5,901), weighted; averages weighted by EU15/NAS10 population. Source: SIBIS 2002/2003, GPS.

[27] Source: New Global 2007.

Figure 7: Multilocational eWork and Tele-cooperation (EU15)



Source: Gareis, 2006, based on data from SIBIS 2002/2003, see Empirica 2002 in New Global 2007.

The next table (table 4) shows that 35% of all employees in companies using ICT (in EU10 countries) have remote access to their company's computer network.

Table 4: Internet access and access to company's computer networks in Europe (EU10)

	Companies with Internet access		Companies with broadband Internet access		Share of employees with Internet access*		Remote access to company's network	
Weighting scheme	% of empl.	% of firms	% of empl.	% of firms	% of empl.	% of firms	% of empl.	% of firms
Total(EU10)	95	93	76	69	n.a.	43	35	16
By firm size								
Micro (1-9 empl)		89		62	n.a.	51		12
Small (10-49 empl.)		98		75	n.a.	29		22
Medium (50-249 empl.)		99		83	n.a.	33		43
Large (250+ empl.)		99		84	n.a.	44		60
By sector								
Food & beverages	95	88	72	64	n.a.	25	35	14
Footwear	96	89	75	62	n.a.	28	17	10
Pulp & paper	99	94	80	68	n.a.	40	56	21
ICT manufacturing	100	99	84	79	n.a.	74	69	35
Consumer electronics	98	97	87	74	n.a.	80	51	32
Shipbuilding & repair	100	100	87	86	n.a.	30	41	27
Construction	95	90	72	64	n.a.	47	25	13
Tourism	93	90	72	68	n.a.	53	38	13
Telecommunication	100	99	88	85	n.a.	90	74	46
Hospital activities	100	98	85	78	n.a.	41	39	34

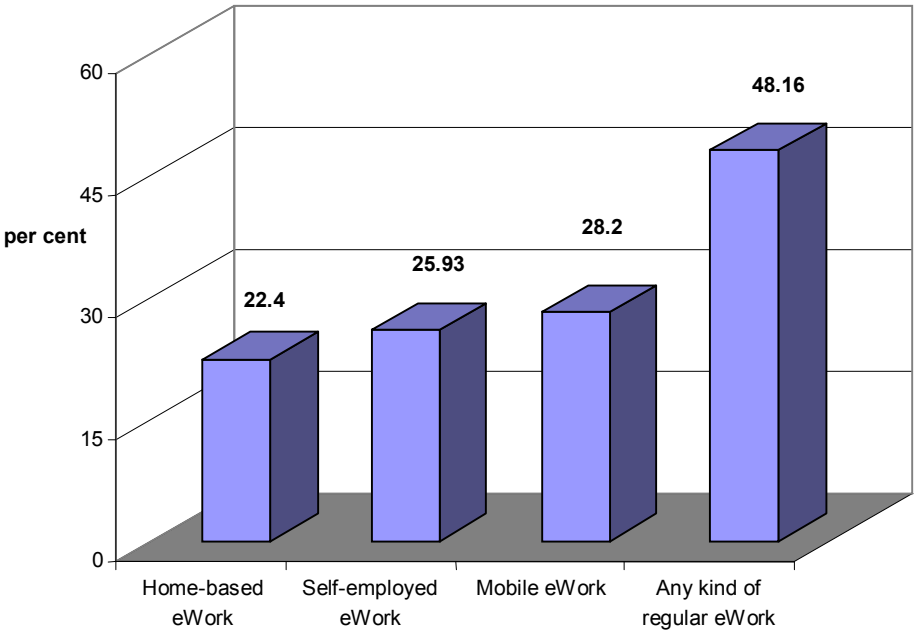
*Read: "In the companies surveyed, on average, 43% of employees have access to the Internet at their workplace"

Source: eBuisness Watch, 2007.

It is interesting to see that the high rate of mobile eWorkers and persons tele-cooperating in Finland is at least partly the result of direct and indirect support by the government and its

ministries (eWork 2001 and eWork 2002, 2001/2002, p. 70). The next diagram (figure 8) shows the rates of different types of eWork in Finland in 1999 (in % of all enterprises).

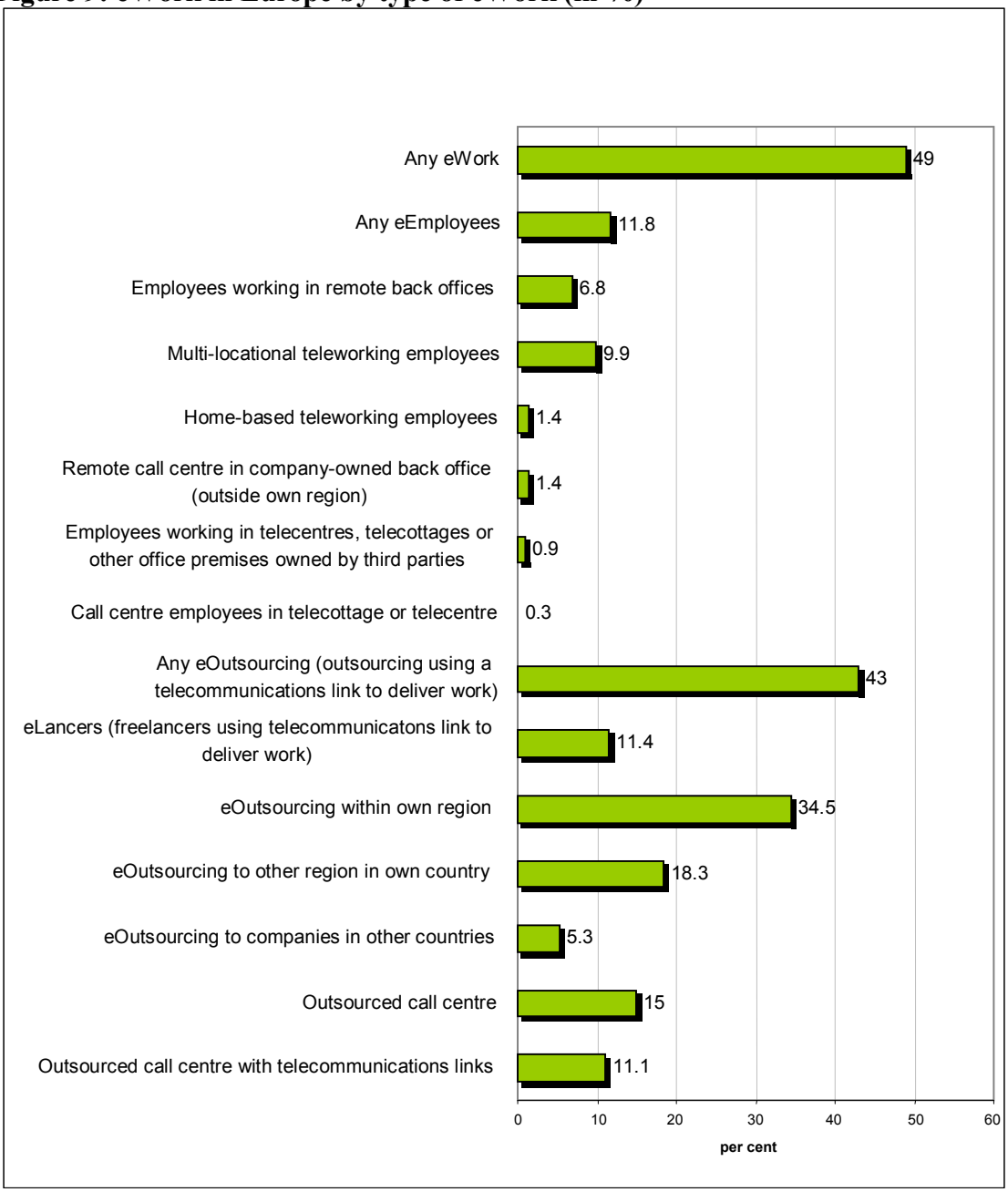
Figure 8: Enterprises practising different types of eWork in Finland



Source: ECaTT study from 2000 (Ten Countries in Comparison, Bonn, 2000-06-08), eWork 2002 and eWork 2003, p. 69 (ECaTT 2000).

It is much more common to find the new technologies supporting mobile eWork (multi-locational teleworking) – approximately one European employer in ten – than teleworking based solely at home. Furthermore, we can see from the next chart that employers are already making significant use of ICT to carry out work remotely (eWork 2001 and eWork 2002, 2001/2002, p.27).

Figure 9: eWork in Europe by type of eWork (in %)



Source: EMERGENCE European Employer Survey, 2000 (IES/NOP) Weighted figures; % of establishments with >50 employees in EU15 plus Hungary, Poland and Czech Republic. Weighted base: 7305 cases.

The use of PSs very much depends on the quality of ICT support for mobile workers in terms of usefulness and usability. It can therefore be assumed that the numbers of mobile eWorkers will increase in line with the rapid increase in the number of people using a PS occasionally for their work. Taking into account the micro-mobility of workers, it can even be expected that in future nearly every worker will use a PS for his/her occupation, albeit not in all cases with high intensity.[28]

Under some circumstances, time and place of work no longer seem to be relevant and the boundaries between working time and leisure time seem to be disappearing. Once workers use PSs, they choose different working locations, such as other locations belonging to their

[28] Mobile eWorkers are those mobile workers using ICT/PSs with high intensity.

employer, clients' premises, hotels and meeting venues, teleservice centres and temporary locations while on the move. The possibility of communicating and interacting with colleagues and customers by means of PSs will lead to the habitual use of such systems by every worker, as can be predicted from the current use of mobile phones.

2.3.2 Categories and numbers of workers affected

While still regarded by many as "executive toys", PSs are increasingly used by sales persons, technical support, delivery, restaurant and maintenance staff, etc.[29]

As indicated by the increase in the numbers of mobile eWorkers, the relationship between physical mobility and ICT support for work, namely in the form of environments for mobile eWork, is a strong one. By avoiding disconnection from communication and information networks ICT support allows closer contact with customers and value chain partners. It also allows more efficient use of otherwise unproductive time, especially during travel. Therefore mobile eWork can be expected to keep growing rapidly over the coming years (Gareis 2006). The indicator SIBIS (SIBIS 2002/2003) shows that 66% of EU15 workers are interested in some type of telework, while in Denmark, for example, the figure is 79%.

The BISER (BISER 2004) statistics from 2003 (table 5) focus on the European regions and show for the BISER region[30] of "Central Macedonia" a share of 0.5% mobile eWorkers (compared with 55% for mobile phone users, 25% for computer users and 12% for Internet users). By contrast, the "Berkshire, Buckinghamshire, Oxfordshire" region was reported as having 13.3% mobile "teleworkers" (mobile eWorkers) – and additionally 18.5% teleworking at home – compared with 80% mobile phone users, 78% computer users, 72% Internet users). The average of mobile eWorkers over all BISER regions in 2003 was 4.7%, a number which is comparable with the 2002 EU15 rate of 4% (SIBIS).

Mobile work can cause a number of problems related to an interrupted communication flow between mobile workers and their colleagues, superiors and customers. Because ICT supports mobile workers, it also makes it possible to increase mobile work, and ICT plays a powerful role as a driver of physically mobile work (Gareis 2006). The BISER data indicates that there is indeed a trend – made possible by ICT – towards the use of multiple locations for working: most persons who spend time eWorking at one "atypical" working location do so at other types of working location as well. It seems that once workers are equipped with a PS and remote access, they are willing (or asked) to work wherever it suits their tasks, demands or personal preferences (BISER 2004).

Regarding the proportion of weekly working time spent at mobile working locations, there is a wide spectrum: some mobile eWorkers spend almost their complete working time at mobile locations, others only a few hours per week (BISER 2004). As BISER data shows, it can be assumed that the percentage of mobile eWorkers decreases with increasing distance from economic centres and communication nodes, so the picture is not an equally clear one in all BISER regions (BISER 2004).

The BISER project found a core-periphery pattern of diffusion of phenomena such as multi-locational work and tele-cooperation and of employment in ICT-producing and utilising

[29] 63% of companies in the region of Stuttgart, Germany, supply their employees with a mobile phone; source: http://www.livinglabs-europe.com/

[30] The BISER study defines specific regions for the analysis.

sectors and occupations. This general pattern is influenced, however, by a significant north-south divide. The diffusion of mobile eWork (and tele-cooperation) appears to be determined less by national factors than by centrality of location within each Member State, and overall levels of regional income as measured by GDP (gross domestic product) per capita. This is especially true for tele-cooperation (BISER 2004).

Table 5: Spread of multi-locational work and tele-cooperation in BISER regions

Region	Multi-locational work			Tele-cooperation
	Teleworking at home	Mobile teleworking	Any	
Brittany, FR	0.9	1.7	2.6	29.1
Castile-Leon, ES	2.5	1.3	3.0	17.7
Central Macedonia, MK	3.0	0.5	3.5	2.4
Ile-de-France, FR	3.3	3.5	6.3	47.2
Languedoc-Roussillon, FR	3.4	3.4	5.6	26.8
Catalonia, ES	4.5.	2.9	6.2	26.2
Nord/Pas-de-Calais, FR	4.5	4.0	7.6	34.4
Tuscany, IT	4.6	1.4	6.1	30.5
Sicily, IT	5.2	1.4	5.9	21.5
Lazio, IT	6.2	7.3	10.7	27.1
Lombardy, IT	6.5	5.7	11.0	38.7
Liege, BE	6.7	4.1	9.2	34.7
Lisboa e Vale do Tejo, PT	7.0	5.9	11.2	37.9
Tees Valley and Durham, GB	8.2	4.6	11.0	38.7
Friesland, DE	8.6	4.7	11.1	38.9
Salzburg, AT	8.7	1.7	9.3	52.3
Mecklenburg-West Pomerania, DE	8.9	4.9	11.3	41.5
Border, Midlands and Western, IE	9.1	3.1	11.7	31.2
Central Finland, FI	9.7	5.3	13.4	40.3
Magdeburg, DE	9.8	2.6	10.8	38.4
Braunschweig, DE	10.0	3.9	13.4	46.1
Greater Manchester, GB	11.7	8.2	16.0	43.4
Leicestershire, Rutland, Northants. GB	12.0	7.4	15.7	53.5
Stuttgart, DE	12.0	7.4	15.7	53.5
Fyn, DK	12.8	4.1	14.2	43.8
Smaland and Islands, SE	14.3	8.7	18.8	48.6
Berk-, Buckingham-, Oxfordshire, GB	18.5	13.3	26.7	61.1
Darmstadt, DE	20.5	4.9	22.7	55.6
AVERAGE	8.7	4.7	11.6	38.9

Source: BISER RPS 2003, weighted.

A precondition for the use of PSs for computing and communication activities for professional purposes is the connection of such systems to a communication network, either the Internet, an extranet or a company's computer network. For this reason, statistical data

about the possibility of remote access to company computers is of some interest. For example, the Eurostat E-commerce (electronic commerce) database (Data 2001-2002) shows that in Austria in 2001 85% of enterprises were already using the Internet. Only 4% answered that they either were not planning to use the Internet or did not yet know, while from 7% answers were not available. The survey covered the business activities manufacturing, distribution, hotels & accommodation, transport & communication, auxiliary financial services and business services, with the use of Internet differing very little between the categories. In the field of financial activities the use of ICT is traditionally high, while small companies do not use the Internet as much as large ones.

Among enterprises with a web presence by far the most common services provided were the marketing of products (81% of enterprises with a web presence) and facilitating access to catalogues and price lists (44%). Among other Internet services, the use of the web to deliver digital products was particularly important in business services, and this sector and the transport and communications sector were the most likely to provide mobile Internet services (8% of enterprises with a web presence).[31] Among the EU15 5% of all enterprises provide mobile Internet services, which is again an indicator of occupational Internet use.

Bearing in mind the increase in Internet and computer use since 2002, it seems reasonable to assume that by now about 25% or even more of the population in the above-mentioned countries is equipped with PSs that allow access to the Internet. We can assume that this number is increasing rapidly and across all countries because most mobile phones now produced and sold are Internet-enabled. However, the number of Internet-enabled phones is not a reliable measure of the number of people actually using this function. With regard to the occupational use of PSs these numbers again are only useful as indicators of the increase in use.

Table 6: Access to Internet through selected devices, 2002 (%)

	DK	DE	EL	ES(1)	IT	LU	AT	PT	FI	SE (2)	UK
Proportion of households with access to Internet (3)											
Have access to Internet	56	43	12	17	27	40	31	16	44	:	50
Have no access to Internet	44	57	87	83	71	60	65	84	56	:	50
Households with access to Internet: proportion with access through selected devices (multiple answers possible) (3)											
Desktop computer	95	92	96	95	:	91	92	90	84	91	85
Portable computer	15	14	6	8	:	19	16	10	17	19	18
Handheld computer	2	1	0	0	:	5	2	:	:	2	:
Television (digital television or set top box)	0	1	0	0	:	1	3	:	:	5	8
Mobile phone used alone (WAP, GPRS)	6	8	6	1	:	15	13	9	16	8	10
Games console	0	1	0	:	:	4	4	:	:	5	:
Other device	0	1	0	0	:	0	1	:	:	5	:

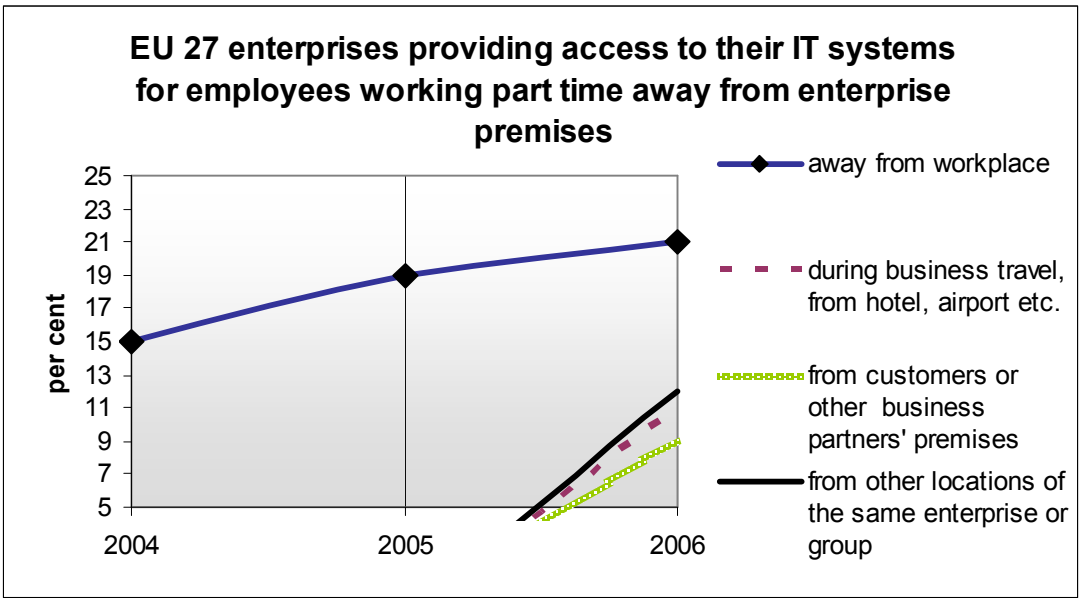
(1) Other device includes games console.
(2) Mobile phone used alone includes also mobile phone used with a portable computer.
(3) Proportion of do not know / no answer is not shown.

Source: Information society statistics, Data 1996 – 2002, THEME 4: Industry, trade and service, 2003 edition, European Communities, Office for Official Publications of the European Communities, Luxembourg.

[31] E-commerce and the Internet in European businesses, Data 2001 – 2002, European Communities, 2003, Office for Official Publications of the European Communities, Luxembourg.

In 2006 21% of EU27 enterprises had employees working for part of their time off the enterprise premises but with access to the enterprise's IT systems. The next table does not answer the question of categories and numbers of involved workers; however, the increasing number of employers providing access to their IT-system from remote locations is again an indicator of the growing importance of the occupational use of PSs, especially the rate of 11% of enterprises whose IT systems are used during business travel.

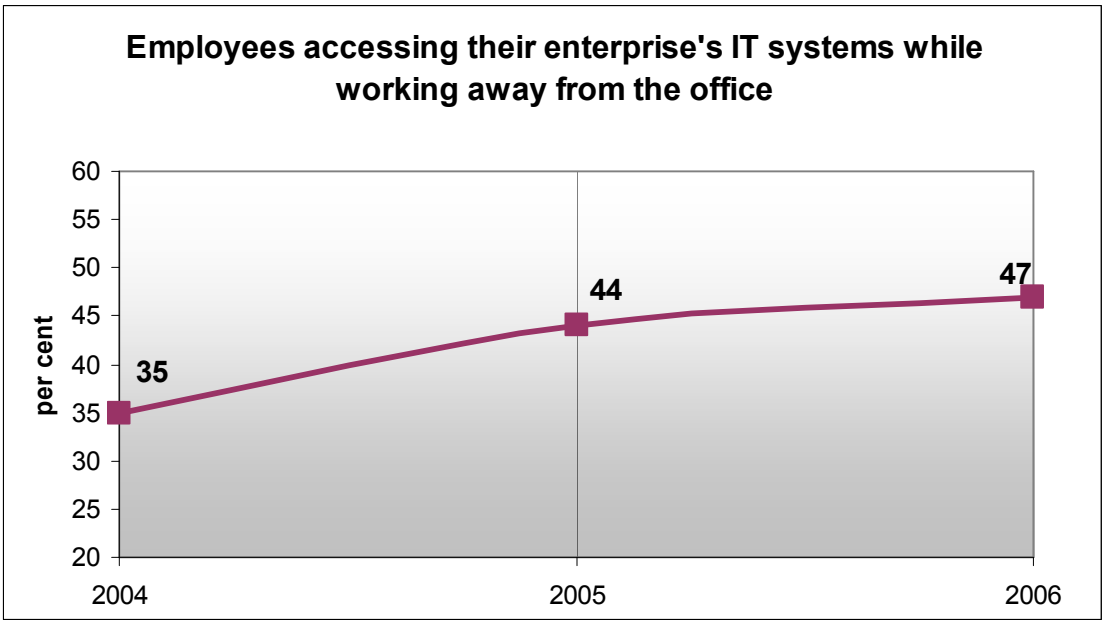
Figure 10: Enterprises providing access to their IT systems for employees working part time away from enterprise premises



Notes: All enterprises with 10 employed persons or more, excluding the financial sector.
Source: Eurostat, 2008.

Figure 11 shows the proportion of employees accessing their enterprise's IT systems while away from their enterprise premises. Many of them will probably use PSs for this purpose. It seems illogical for about half of all employed persons to be working part of their time away from their enterprise premises and then access the relevant IT systems on their return. In combination with the above diagram the author interprets these statistics as follows: In 2006 21% of all EU27 enterprises had employees working part of their time away from company's premises who accessed the enterprise's IT systems. 47% of all employees working in such enterprises belonged to this category of workers. As a result, if the author is correct, about 10% of all employed persons in the EU27 work part of their time away from their company's or organisation's premises but retain access to their enterprise's IT systems while doing so.

Figure 11: Employees working part of their time away from their enterprise premises and accessing the enterprise IT systems (EU27)



Notes: All enterprises with 10 employed persons or more, excluding the financial sector.
Source: Eurostat, 2008.

Trying to categorize mobile eWorkers and going into more detail by using case studies or scenarios would highlight the particular characteristics of such sectors as engineering, manufacturing or healthcare.

The engineering sector is knowledge-intensive and needs access to global competencies and information. It involves complex processes and products and widely dispersed stakeholders, and requires a multi-functional perspective.

The manufacturing sector constantly needs to improve productivity and quality, and requires the development of production processes.

The healthcare sector is knowledge-intensive, involves team work, widely dispersed stakeholders and complex processes, and constantly needs to improve productivity, service and quality, and to guarantee continuity of care.

Analysing the use of ICT and PSs in the above-mentioned sectors, no distinction could be found from a generic point of view that could help to define categories of affected workers for the purposes of this study.

One challenge from the perspective of mobile eWorkers is to explore how portable technology can be used to empower workers (individuals and teams) to build innovative work environments.

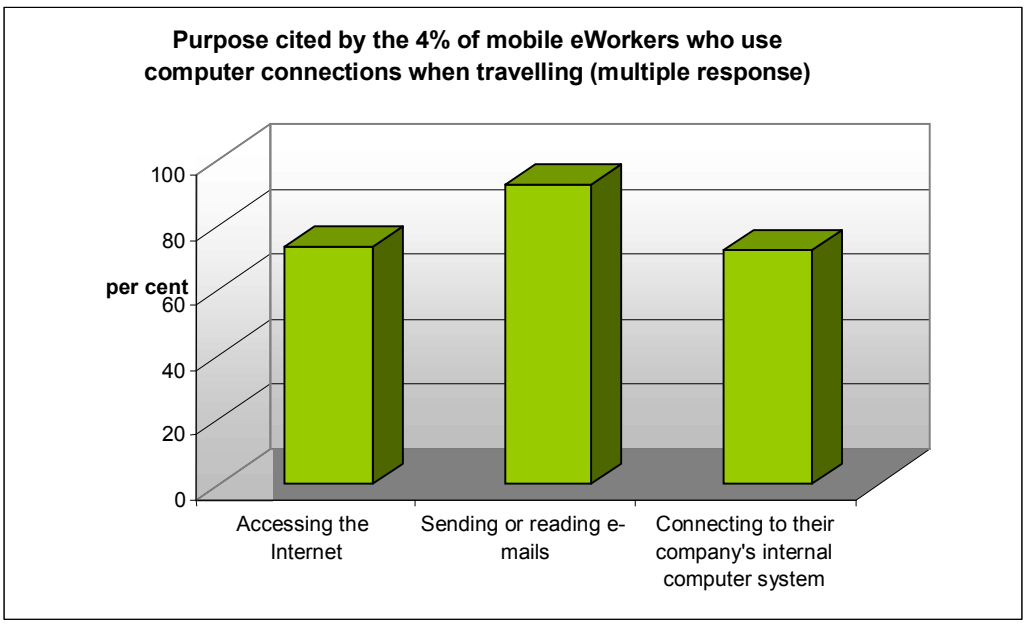
PSs can support access to data (information, knowledge) and facilitate collaboration. In the future, most workers in developed economies will need access to data and support through collaboration. With an increasing need for flexibility and mobility, the number of mobile eWorkers (and the use of PSs) will increase further.

For studying the impact on occupational health and safety, types of work, categories of workers, and types of PSs are of less importance than the work environment of mobile eWorkers.

2.3.3 Typical activities and tasks

Office workers and knowledge workers mostly use PSs for asynchronous e-mail communication and provision of data (information) or the use of their company's software applications. Knowledge workers live in a "virtual environment" using collaboration tools. Non-office workers in sectors such as field maintenance and healthcare are mainly connected to their company's computer systems using special applications.[32] SIBIS (SIBIS 2002/2003) data from 2002 shows that 92.4% of meWorkers communicate via asynchronous e-mails and about 70% use the Internet, an extranet[33] or the company's applications. Besides e-mails the typical office applications, such as address book and calendar, are of major importance for all mobile eWorkers. Thus – back in the main office or at home – synchronisation of related data (and of e-mails with an e-mail management and archiving application) is an important ICT-related task. Synchronisation also guarantees a back-up of such data. Data from SIBIS shows that activities are also being carried out on the move and not only in instant offices: 37% used PSs for data transfer in such a situation.

Figure 12. Activities of mobile eWorkers in 2002



Notes: Base: All persons employed (N=5,100); weighted by EU15 population.
Source: SIBIS 2002, GPS.

As figure 12 shows, after telephone conversations receiving (and sending) emails is the most relevant activity for which PSs are used. E-mail is used less for outgoing[34] than for incoming communication, and it is much less frequently used for managing urgent situations than the

[32] The European Commission's status report "eWork 2001" eWork 2001 and eWork 2002, 2001/2002 used the categories self-employed, managers, other white collars and manual workers.
[33] In 2007 16 % of all EU27 enterprises used extranets (Eurostat, all enterprises, excluding the financial sector (10 employees or more)).
[34] For convenience.

mobile phone[35]. Furthermore, e-mail was mostly used by those survey participants who stayed overnight away from home; the typical scenario was to check e-mails at a hotel (Gareis 2006). Women are much less likely to be mobile eWorkers than men. 71% of all multi-locational workers are male. Together with the results of earlier empirical research, this result indicates that the increase in work-related (geographical) mobility which has been made possible by ICT affects male more than female members of the workforce. Based on BISER we can conclude that men enjoy more ICT-enabled geographical flexibility than women (BISER 2004).

Mobile non-office workers are often not mobile eWorkers, because they do not use ICT very intensively. Their use of PSs tends to be more occasional.

When trying to categorize typical activities and tasks a distinction can and should be made between mobile white-collar workers – who mainly use PSs as a tool for management and office tasks – and other workers – who mainly use PSs for their work schedule and for background information.

Typical activities and tasks using PSs can be described using the categories mobile blue-collar workers and other workers. White-collar workers are often mobile eWorkers (high-intensity ICT users) while blue-collar workers tend to use PSs only occasionally. **PSs are ICT tools used for ICT-related activities regardless of the sector of use; therefore the work environment of mobile workers, which differs very much between office workers and others, is of greater importance for occupational health and safety.**

2.3.4 Types of work with portable devices and possible OSH risks and OSH management problems

Car manufacturers, telecommunications companies, utilities, security forces, international peace-keeping organisations, hospitals, power suppliers, etc. – all these categories of companies and organisations use PSs. From the point of view of possible OSH risks and OSH management problems three different types of work with portable devices can be identified:

- mobile office work, for which changing working environments and longer periods of concentrated work are typical;
- working with portable devices in the technical support and logistics sectors, for which changing working environments and unfavourable working posture are typical;
- visual display units in vehicles, for which concurrent demands from driving and communication are typical.

[35] Found by an empirical study of a group of meWorkers. O'Hara K, Perry M, Sellen A, Brown B (2002). "Exploring the Relationship between Mobile Phone and Document Activity during Business Travel".

Table 7: Examples of types of work with portable devices and the related typical OSH risks and OSH management problems

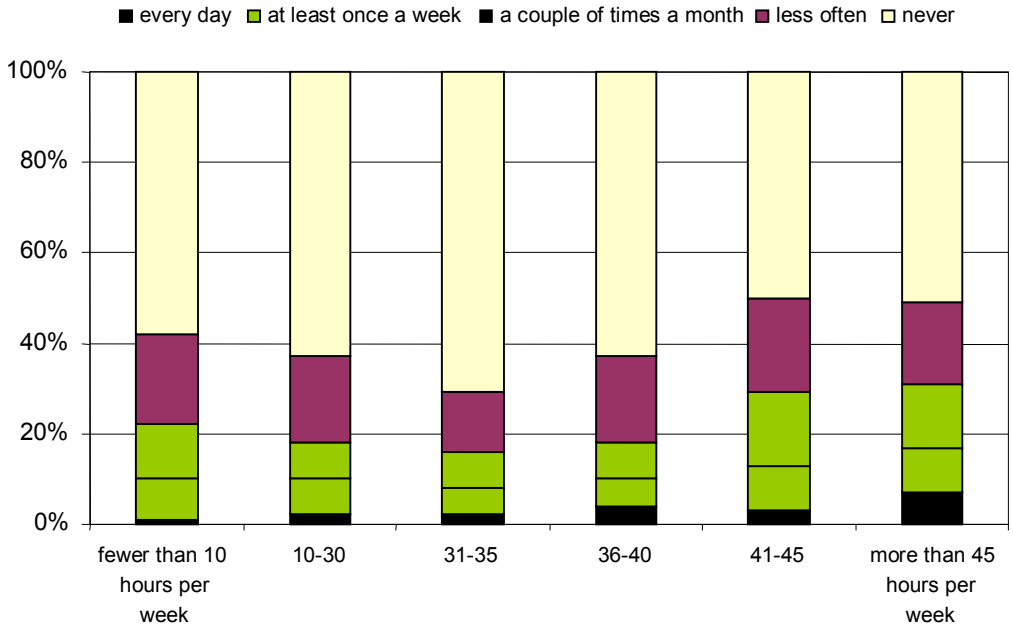
Types of work with portable devices (examples)	Typical OSH risks	Typical OSH management problems
Mobile office work ▪ Business work ▪ Health care in hospitals ▪ Insurance agents ▪ Door-to-door retailing	▪ Longer periods of work at non-ergonomic work environments ▪ Stress ▪ Insufficient integration into organisational flow of information	▪ Limited control by the employer ▪ Changing working environment ▪ How to conduct risk assessment?
Working with portable devices in the technical support and logistics sectors ▪ Engine field service and diagnostics ▪ Electrical appliance installation and maintenance ▪ Telecommunication network services and maintenance ▪ Gas and power suppliers ▪ Aircraft services and maintenance	▪ Ergonomic risks ▪ Stress ▪ Eyesight risks ▪ Accident risks at dangerous workplaces	▪ Changing working environment ▪ Unfavourable working posture ▪ Limited control by the employer ▪ How to conduct risk assessment?
Visual display units in vehicles ▪ Pilots ▪ Airport ground operations ▪ Ambulance services and emergency care ▪ Public transport	▪ Accident risks through distraction ▪ Stress through communication while driving	▪ Limited control of the employees' behaviour by the employer

2.3.5 How portable systems influence the boundary between work hours and private time

A new question, introduced in 2005 into the European survey on working conditions, assesses the extent to which work impinges on non-working life. It asks workers whether they are contactable in connection with their main paid job outside normal working hours. The growth of faster communication technologies (phone lines, mobile phones and broadband Internet/e-mail) over the past five years has made such contact possible for the majority of Europeans. For certain categories of workers, or rather for those with particular roles – e.g. supervisory responsibilities, or the self-employed – this can blur the boundaries between work and non-work. The same communication technologies that make contact possible may also make further work possible, effectively extending working hours. In essence, this can be seen as a form of negative "flexibility". It is notable that managers (those with staff working under their supervision) report this type of contact more than do other workers, and that men, in general, appear to be more affected than women (European survey on working conditions 2007).

About 18% of workers have out-of-hours contact every day or a least once a week, extending their working time to more than 45 hours a week. It seems obvious that mobile eWorkers and mobile workers will have an even higher rate.

Figure 13: Extent of out-of-hours contact by length of average working week, EU27 (%)



Source: European survey on working conditions 2007.

About 28% of men with supervisory responsibilities have out-of-hours contact every day or at least once a week. The lower rate for women probably results from the smaller number of women in roles with supervisory responsibilities.

ICT tools to support knowledge management in global process distribution and global networked organisations are tools that set up a "virtual world" with workers in different time zones. It is immediately apparent that knowledge workers in global teams cannot work with their colleagues only asynchronously (by using e-mail or collaboration tools). There is also a need for synchronous communication and data exchange. This will lead to a situation where traditional working time patterns are much less important than they are today. Together with the irrelevance of the place of work for many collaborative activities (especially for some mobile workers), we can see a development towards working in a "virtual world" irrespective of time and workplace. This development will first affect knowledge workers.

A key topic in the discussion of individualised forms of virtual collaboration is their impact on the balance between work and family commitments. Data from a representative survey of Finnish workers leaves no doubt that ICT – in combination with new management practices – has enabled work to "slop over" into leisure time, to the possible detriment of the interests of the family. The question is whether this blurring of boundaries which have traditionally drawn a clear line between work and private life impacts negatively on the health of the individuals affected. The large majority of knowledge workers who use ICT (including mobile phones) to stay connected to their work during their leisure time do not mind.[36] One explanation is that they realise that they also benefit from the increased flexibility in managing work and leisure time schedules. Knowledge workers use ICT to extend their working hours, in particular using

[36] However, 42 % of employed people in Germany, for example, have an e-mail address, and according to a study of BITKOM that was mentioned in the German newspapers (21 August 2008, WAZ, Der Westen), 37 % of them would like to have pre-defined days without any duty to read e-mails.

spare time during commuting for work-related tasks, but this is not necessarily considered a problem by those concerned. Most studies of individualised virtual collaboration find **longer working hours are the result of working remotely. Remote workers are often unable to "shut off the stress response after the end of the work day", and that this "contributes to the wear and tear on the body." They conclude that" lack of time for rest and recovery from work could be an even more important health risk in modern society than the actual level of stress during work"**. A study based on data from a comprehensive sample of the Swedish workforce has shown that perceived work-life imbalances are associated with a higher likelihood of gastrointestinal and cardiac problems and higher frequency of mood and sleep disturbances and headaches (New Global 2007).

Although the BISER data confirms the results from other research that eWorkers tend to work longer hours than non-eWorkers (see above), the interrelation may be less straightforward than it seems. Recent research to control for other variables which can be expected to influence working hours as well (occupation and occupational status, sector, tasks, decision-making power, etc.) suggests that eWork itself does not impact on working hours, but rather occurs in jobs that anyway tend to be characterised by long working hours (BISER 2004).

According to the 2002 Working Life Barometer for Finland, a country which has pioneered mobile phone use, almost 40% of wage and salary earners have been carrying out work tasks in their leisure time by means of a connection to their employer via mobile phone or ICT network (Gareis 2006).

A case study on mobile and distributed work by knowledge workers showed that the employees were working mainly in their offices, meeting in other places and at home. However, they spent a considerable amount of time outside their office, i.e. travelling or attending meetings and inspections. During business trips, they also worked in airports, trains, hotel rooms and in customers' offices using PSs. The personnel had flexible working hours and were used to working with mobile phones, laptops and videoconferences provided by the company.

That study revealed three major problems caused by distributed and mobile teamwork:
(i) Lack of shared project identity,
(ii) Lack of shared understanding of the project totality,
(iii) Lack of trust and collaboration between headquarters and regions.[37]

2.3.6 Possible evolution of the technology and future use of portable systems

The main corporate goals associated with the use of PSs are an increase in mobile workers' productivity, enhancement of interactions with customers and improvement in the collaboration with colleagues and partners. The most important factors in achieving such goals are improvements in data availability and better communication. Innovative new services characterized as unified communication will go beyond voice to video, instant communication, and video conferencing, applications that already are used today by knowledge workers and managers.

[37] Virpi Ruohomäki "Distributed and Mobile Work – promoting Collaboration with the Teamwork Game" in: Matti Vartiainen (Ed.): Workspace Methodologies – Studying Communication, Collaboration and Workscapes, Helsinki University of Technology, Report 2006/3, Espoo.

The development of Internet services and applications and tools using the Internet is well in line with these goals. For the purposes of this study, the current ideas and discussions around the evolution of the Internet can best be dealt with by reference to the conceptual ideas of Web 2.0. The most important Web 2.0 concept is that the Internet is not only a communication network, but also an electronic platform for computing tasks that can run on servers or even on local systems. This important concept is not new: it has already been implemented by Application Service Providing (ASP)[38]. The ASP concept is particularly important for PSs, because with it the design of PSs can be concentrated on the support of communication tasks, whilst computing tasks are then run on an Internet platform. This opens the way for small and lightweight PSs and especially for wearable systems. The human/machine interface can be designed for communication tasks, for transmitting commands and for viewing results.

Mobility, multimedia and the explosion of communities are three major trends in the information society today. PSs enable mobility supporting multimedia communication within communities.

Some universities, research institutes and companies around the world (for example, in California, Pennsylvania, Australia, Austria, Japan, Sweden, etc.) have been developing – and since 2008 selling – products with brain/computer interfaces based on electroencephalography (EEG) technology. EEG is the measurement of electrical activity produced by the brain as recorded by electrodes placed on the scalp[39]. Brain waves and muscle, skin or nerve activity are detected by sensors attached to a headband[40]. The person's intended move can be "translated" into navigation commands, even for already implemented user interfaces. This research reveals the potential for the development of innovative user interfaces for portable and wearable systems.

2.4 Technological development and nanotechnology

Web 2.0 is a term describing the main trend in the use of World Wide Web (WWW) technology and web design that aims to enhance creativity, information sharing and, most notably, collaboration among users.[41] Although the term suggests a new version of the WWW, it refers not to an update of any technical specifications, but to changes in the ways software developers and end-users use the Web.[42]

Web 2.0 websites allow users to do more than just retrieve information. They can build on interactive facilities to provide "network as a platform" computing, allowing users to run software applications entirely through a browser. Users can own the data on a website and exercise control over that data. These sites may have an "architecture of participation" that encourages users to add value to the application as they use it.[43]

What is the relevance of Web 2.0 ideas for mobile workers/mobile eWorkers and the further development of ICT tools, especially PSs, supporting their work? **Mobility, multimedia use**

[38] An application service provider (ASP) is a business that provides computer-based services to customers over a network. Software offered using an ASP model is also sometimes called On-demand software or software as a service (SaaS), http://en.wikipedia.org/wiki/application_service_provider.
[39] http://en.wikipedia.org/wiki/electroencephalography
[40] This technology is currently being launched in products for medical use and in gaming tools.
[41] http://en.wikipedia.org/wiki/web_2.0
[42] http://en.wikipedia.org/wiki/web_2.0
[43] http://en.wikipedia.org/wiki/Web_2.0

and the **explosion of communities** are the three major trends in the information society today. We can forecast that these trends will also influence the behaviour of workers and will dominate the future development of ICT solutions. The Internet as a "virtual world" will be used to collaborate on such platforms and to transform results back into reality.[44] Furthermore, the "Internet of Things"[45] imports real objects (and subjects) into the Internet, thus giving data (information) about an object's/subject's attributes, such as position or direction of movement. This approach includes things that cannot have communication behaviours of their own.

In computing, **ambient intelligence** (AmI) refers to electronic environments that are sensitive and responsive to the presence of people. In an ambient intelligence world, devices and systems work in concert to support people in carrying out their everyday activities and tasks using data (information, knowledge) that is hidden in the network connecting these devices and systems. As these devices and systems become smaller, more connected and more integrated into our environment, the technology disappears into our surroundings until only the user interface remains perceivable by users.[46]

The **ambient intelligence paradigm** builds upon **ubiquitous computing** and **human-centric computer interaction design** and is characterized by systems and technologies that are:

- **embedded**: many networked devices/systems are integrated into the environment;
- **context aware**: these devices/systems can recognize users and their situational context;
- **personalized**: they can be tailored to the user's needs;
- **adaptive**: they can change in response to the user;
- **anticipatory**: they can anticipate the user's desires without conscious mediation[47].

Ubiquitous computing is a post-desktop model of human/computer interaction in which information processing has been thoroughly integrated into everyday objects and activities[48]. In contrast to the desktop paradigm, in which a single user consciously engages a single device/system for a specialized purpose, in ubiquitous computing many computational devices and systems are engaged simultaneously in the course of ordinary activities, and persons may not necessarily even be aware that they are using systems.

Bearing these trends in mind, we can forecast the application of wearable systems that use sensors to capture data from their environment, whilst being connected to the Internet for the support of collaborative activities. Such emerging technologies will be integrated into innovative workplace designs and special solutions for the support of mobile workers/mobile eWorkers.[49]

Other technological developments may also influence the evolution of PSs:

- Reusable paper contains a photochromic compound that makes ink disappear when hit by direct heat.[50]

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[44] An example of this Internet usage evolution is Second Life, an Internet-based virtual world video game, http://en.wikipedia.org/wiki/second_life

[45] In computing, the Internet of Things refers to a usually wireless and self-configuring electronic communication network between objects, http://en.wikipedia.org/wiki/internet_of_things

[46] http://en.wikipedia.org/wiki/ambient_intelligence

[47] http://en.wikipedia.org/wiki/ambient_intelligence

[48] http://en.wikipedia.org/wiki/ubiquitous_computing

[49] Readers interested in the development of wearable systems should read the documents provided by the EU-co-funded project wearIT@work, such as "Empowering the Mobile Worker – Intelligent Clothing" (http://www.wearitatwork.com/).

[50] http://spencerprint.blogspot.com/2008/05/at-gartner-symposiumitxpo-in-las.html

- Further development of tactile and touch user interfaces for computer programs with haptic feedback methods using (multi-) touch screen displays and zooming software as a combined input/output device, accepting even hand gestures with a writing utensil (like a stylus), hand-writing and natural language for input. Non-command interfaces will be implemented using sensors, cameras, and/or brain/computer interfaces which observe the user to infer his/her intentions (see chapter above).
- Solid state memories without moving parts or mechanical actions and with miniaturized form factors with capacities of more than 256 GB.[51]
- Computer systems implemented on one chip only. System-on-a-chip or system on chip (SoC or SOC) refers to integrating all components of a computer or other electronic system into a single integrated circuit (chip).[52]
- Visual display units (monitors) with three-dimensional video output that can be viewed from different angles and exposed to direct sunlight[53] or holographic displays[54].
- Fuel cells[55] providing electric power[56].
- Very light, flexible and low-cost organic electronics[57] that also can be used for electronic paper[58] or liquid crystal devices (LCD).

Nanotechnology

Last but not least, nanotechnology will have an influence on the further development of PSs. The term "nanotechnology" refers to a field whose theme is the control of matter on an atomic and molecular scale. Generally, nanotechnology deals with structures of the size of 100 nanometres or smaller, and involves developing materials or devices on that scale. Nanotechnology mainly consists in the processing, separation, consolidation and deformation of materials by one atom or one molecule.[59] Nanotechnology is extremely diverse, ranging from novel extensions of conventional device physics to completely new approaches based upon molecular self-assembly and developing new materials with dimensions on the nanoscale. There is even speculation as to whether we can directly control matter on the atomic scale. Nanotechnology raises many of the same issues as the introduction of any new technology, including concerns about the toxicity and environmental impact of nanomaterials, their potential effects on global economics and speculation about various doomsday scenarios.

In future it will be possible to use nanotechnology to build portable ICT devices/systems, especially portable computers. As scientists have raised concerns that the basic building blocks of nanotechnology pose a potential new class of risk to health and the environment,[60] these risks must also be considered in relation to occupational health and safety. For example, nanotechnology is already a key technology in surface finishing. A specific risk with regard to

[51] http://en.wikipedia.org/wiki/solid_state_disk
[52] http://en.wikipedia.org/wiki/system-on-a-chip
[53] see a product example at http://www.lightspacetech.com/
[54] see a product example at http://blog.wired.com/gadgets/2008/06/usc-lab-creates.html#more
[55] http://en.wikipedia.org/wiki/fuel_cell
[56] A micro fuel cell is a portable power source for low power electronic devices that converts chemical energy into useable electrical energy. It generates power through the electrochemical reaction of a fuel in the presence of a catalyst, http://www.mtimicrofuelcells.com/technology/how.asp.
[57] Organic electronics, or plastic electronics, is a branch of electronics that deals with carbon-based conductive polymers, plastics, or small molecules, http://en.wikipedia.org/wiki/organic_electronics.
[58] http://en.wikipedia.org/wiki/electronic_paper
[59] Lauterwasser, Christoph (ed.) (2005). "Opportunities and risks of Nanotechnologies", Allianz Group report in co-operation with the OECD International Futures Programme, Allianz Center for Technology, München, Germany.
[60] Lauterwasser, Christoph (ed.) (2005). "Opportunities and risks of Nanotechnologies", Allianz Group report in co-operation with the OECD International Futures Programme, Allianz Center for Technology, München, Germany.

occupational health and safety arises from the possibility of constructing computers so small that they can be integrated into clothes and that such "undetectable" systems could be used to control employees. For these reasons, the impact of nanotechnology must also be considered when analysing the impact of portable devices/systems on occupational health and safety.[61]

Given these examples of the accelerated development of technology, it will be readily understood that the development of PSs and related ICT infrastructure is unlikely to end in the near future. With changing patterns of work organisation and altered tasks and activities, PSs will gain in importance.

2.5 Work of tomorrow – future working patterns

Besides all the functions described in the preceding chapters, PSs have a role to play in helping a mobile worker "on the move" to find out where, for example, appropriate spaces and services are available at that location. PSs will function as the tool for ordering assistance, services and resources.

However, PSs will have a much bigger role to play in enabling new forms of work. The purposes which have traditionally required physical mobility may increasingly be achieved by electronic means, certainly in the case of many office workers, and especially knowledge workers. Companies are therefore constantly seeking out alternatives to physical mobility in order to be able to control costs while still enjoying the benefits of close interconnectedness with value chain partners and customers (Gareis 2006). Since portable technologies enable mobile eWork, work is becoming more and more multi-locational and dispersed.

In a multilocal work environment mobile eWorkers will perform computer-supported collaborative work (CSCW) using PSs and docking stations. New collaboration support technologies, such as instant messaging and instant video conferencing for synchronous communication, may well play a role similar to that of e-mail today for asynchronous communication.

Knowledge workers of the future will use Internet applications that set up an "architecture of participation"[62] where users can contribute website content in such a way as to create network effects. Such architecture of participation tends to foster innovation by pulling together contributions from (widely) distributed, independent contributors. Wikis are (by now well-known) examples of this phenomenon[63]. Architectures of participation can also be used to support the work of blue collar workers "in the field", since many types of work in this sector also involve data/information/knowledge management. Examples of this would be: dealing with work schedules, background information, problem-reporting or reports on work done.

"Virtual" environment issues, flexible and collaborative working practices, location-independent approaches and incorporating emerging technologies into new workplace and teamwork concepts will be the triggers for new work patterns in the future. The forms of work

[61] Sutcliffe, Hilary; Hodgson, Simon (October 2006). "Briefing paper: An uncertain business: the technical, social and commercial challenges presented by nanotechnology".

[62] O'Reilly and John Battelle: Opening talk of the first Web 2.0 conference, San Francisco, 2004, http://en.wikipedia.org/wiki/web_2.0.

[63] A Wiki is a collection of web pages designed to enable anyone who accesses it to contribute or modify content, using a simplified markup language. Wikis are often used to create collaborative websites and to power community websites. The collaborative encyclopedia, Wikipedia, is one of the best-known wikis. Wikis are used in business to provide intranets and knowledge management systems, http://en.wikipedia.org/wiki/wikis.

carried out by office and by non-office workers will differ in the detail; but in principle PSs and related technologies will be able to, and indeed will, support tomorrow's work patterns generically.

"Virtual" environments will be connected to the real environment of the "Internet of Things". Passive and active sensors will monitor people's activities, potentially without those observed being aware of it. This poses the question as to who in future will be able to control the "virtual" environment connected to the "Internet of Things". **Soon humans will become part of technical systems – functioning as components**, and prompting the question: who is the device – the human or the technical environment? There is a good chance that future work will be organised so that the worker is not the acting subject but rather the object of an automatically controlled process. PSs in the form of wearable devices will play a large role in this process.

2.6 Foreseeable future use of portable systems

This chapter gives a forecast for the future use of PSs. In 2008, CNET Networks[64], USA, conducted an interesting, so-called "instant poll" on their website, asking visitors to the site which PSs they could least do without. The actual question was "Which gear is a must-have?"[65] What does this question have to do with the future use of PSs?

First of all, it seems obvious that synchronous voice communication is, and will continue to be, the most important functionality of PSs. However, in less than 5 years all mobile phones are expected to be Internet-capable systems.[66] Why?

From a generic point of view, asynchronous and synchronous communication between persons (and within teams) will be the most important functions, supplemented by functionalities that support collaboration with individuals or teams. As mentioned above, communication can best be supported by unified communication channels, collaboration by traditional CSCW applications and – with growing importance – by Wikis[67]. Data (information) will be pulled (traditional method) or pushed (instantly and actively transferred).[68] Applications such as web conferencing enable users to, for example, conduct sales presentations, offer customer support, give product demonstrations, conduct online training, collaborate with colleagues in workgroups and share web surfing sessions with other users.

Secondly, typical laptop functionalities remain important today. Office workers use their laptops mainly as text-editing machines, to write (and read) e-mails or documents, to give presentations with slide shows, and for access to the Internet or remote access to company computer networks. Non-office workers use their laptops mainly for special software applications running on the laptop and for remote access to their company's computer network. However, all these typical functionalities can be implemented by applications running on an Internet platform (ASP concept, including extranets). In the future, the PSs will therefore only be used as a gateway to the Internet platform; modern and personalized

[64] http://en.wikipedia.org/wiki/CNET
[65] From CNET instant poll results, http://polls.cnet.com, a no longer valid WWW address.
[66] Prof. Rahim Tafazolli, The University of Surrey, England: "Next Generation 3D Internet (Post-IP) leading to 4D Mobile Internet", Slide show 31 January 2008, EU consultation meeting "Future Internet".
[67] http://en.wikipedia.org/wiki/wikis
[68] http://en.wikipedia.org/wiki/push_e-mail

browsers will be the user interface for all applications and for unified communication channels. The user will not need to know where data and/or applications are stored.

Thirdly, PSs using the Global Positioning System (GPS)[69] are already common nowadays and their use is increasing. GPS devices are able to determine their absolute location, relative movement (speed, direction) and receive time data. This allows GPS devices to perform as a surveying tool, as an aid to navigation or, for example, as a positioning tool for emergency calls. Location-aware[70] applications use such data. Together with the Internet of Things and the use of RFID tags (radio-frequency identification tag is an object that can be applied to, or incorporated into, a product, animal or person for the purpose of identification and tracking using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader), data about current location and direction of motion facilitates the calculation of the optimal sequence for the performance of tasks in logistics and distribution, for instance. Location-awareness and other data about the work environment and work context (context-awareness[71]) will help PSs to assist workers in a much more straightforward way than today. Location and context awareness can be achieved, for example, by using sensors, cameras, brain/computer interfaces, positioning systems and databases with background information. Future PSs will be user-, location- and context-aware. Location, context and user attributes will be relevant input for many applications and in collaborative tasks. For instance, such data is very useful for supporting safety precautions for fire workers during a mission.

Fourthly, many people responding to the CNET poll replied that portable printers were a must, thus indicating the value of traditional paper. However, a great deal of effort has been put into producing so-called electronic paper displays[72], perhaps in the form of organic electronics[73], and reusable paper (see chapter 2.4 "Technological development and nanotechnology"). E-book readers[74] are very lightweight systems that provide a crisp, clear and paper-like image which is visible indoors and outdoors, including in full sunlight. As soon as such systems can be used like traditional paper, portable printers will no longer be viewed as essential.

Based on distributed object technology standards, future infrastructures and solutions will integrate intelligent and mobile agents, location-/context-aware personalized (user-aware) event-based communication as well as pushes of information. Mobile working will be supported by the integration of PSs into the Internet platform. Dynamic user profiles and context attributes will allow highly adaptive mobile services.

Future services will enable users and user groups to develop their own services, to be creative with respect to content generation, presentation and communication, to interact with a community of users in a group-specific manner, to explore, adjust and set up their own mobile communication environment and information space. There will be a greater degree of interaction with systems and devices in the user's environment, leading to the development of an intelligent environment that is integrated into the service delivery chain and will support

[69] http://en.wikipedia.org/wiki/GPS
[70] http://en.wikipedia.org/wiki/location_awareness
[71] http://en.wikipedia.org/wiki/context_awareness
[72] http://en.wikipedia.org/wiki/electronic_paper
[73] http://en.wikipedia.org/wiki/organic_electronics
[74] http://wiki.mobileread.com/wiki/E-book_Reader_Matrix

advanced communication services for communities of users (adapted from "The Disappearing Computer", 2002).[75]

Furthermore, solutions for which portable systems are particularly suitable, such as mobile-to-mobile payments or the use of portable devices for digital signatures, will become common. In the future PSs will be used, and probably will have to be used, by all workers as the gateway to the "virtual world" set up by the future Internet platform that will come to dominate work environments and influence all types of work and many sorts of activities and tasks.

Smart phones will become the ICT interface most widely used by mobile workers in the near future; **wireless peripherals** such as **keyboards**, **displays** and **backup devices** will be connected, **new scrolling user interfaces** will also provide special text entry techniques, gesture as an interaction technique and **voice input** and **commands** (Lawo 2008).

2.7 Discussion and conclusions

Little statistical data is available about the use of PSs in an occupational environment. Most statistics in this field are for consumer products. However, they do reveal some trends. While in the past innovation in ICT evolved from occupational use, now innovation takes place in consumer electronics and is subsequently adapted for occupational use.

PSs can be classified by their application-oriented design, which means that the systems are mainly intended either for communication or for computing tasks. Systems designed for communication tasks are more miniaturized and lighter than those designed for computing tasks and therefore are more appropriate for supporting mobile work. For this reason, if all PSs were adapted for the use of computing facilities via the Internet or other networks (application service providing [ASP]), this would allow the design of PSs for communication tasks only. Computing tasks could then be run on servers, leaving PSs to control the tasks and receive and display the results.

Technological development will go in the direction of unified communication and information channels that allow multimedia communication (voice, data, text and video) together with all possible related services, such as instant teleconferencing, asynchronous communication and event-driven information pushes.

Typical work using PSs is characterised by activities that can be and are supported by ICT regardless of the profession or job involved. Whether people are working in customs control, facility services, home care or as project managers, most types of mobile work (including micro-mobility) can be – and in the future will be – supported in some way by the use of PSs. It is therefore impossible to categorize the use of PSs by types of work or types of professions. In contrast to service-oriented work, in production-oriented work much less ICT support is possible. However, there is one group of workers in all professions who use ICT to a very high degree. These are the so-called knowledge workers, who typically also use PSs while "on the go" or "on the move".

[75] The Disappearing Computer is a EU-funded initiative of the Future and Emerging Technologies (FET) activity of the Information Society Technologies (IST) research program, see http://www.disappearing-computer.net/, and http://cordis.europa.eu/ist/fet/dc.htm.

Turning to the impact of PSs on occupational health and safety, we suggest making a distinction between office workers and non-office workers. This distinction is mainly connected with the considerable differences in the work environment of mobile eWorkers; these differences lead to differences in the design of PSs, especially when they are ruggedized or to be used outdoors.

It can be shown that the work environment of mobile eWorkers is much worse than that of stationary workers, both in terms of real and "virtual" work settings, space and environmental conditions and in terms of mental/social space requirements. Furthermore, in the majority of cases this work environment changes in the course of the working day, and often cannot be fully controlled by the employer.

Under some circumstances, the time and place of work no longer seem relevant and the boundaries between working time and leisure time are bound to disappear. Once workers use PSs, they choose different working locations, such as other locations belonging to their employer, the premises of customers or clients, hotels and meeting venues, teleservice centres and temporary locations while on the move. The possibility of communicating and interacting with colleagues and customers by using PSs will lead to the habitual use of such systems by every worker, a likely development given the current rate of use of mobile phones.

From the perspective of mobile eWorkers themselves, one challenge will be to explore how portable technology can be used to empower workers (both as individuals and in teams) to build innovative work environments. PSs can support access to data (information, knowledge) and facilitate collaboration. In the future, in developed economies most, or even all, workers will need access to data and the support of collaboration. With an increasing need for flexibility and mobility, the number of mobile eWorkers (and the use of PSs) will also further increase.

PSs are ICT tools used for ICT related activities regardless of the sector of use. Therefore the work environment of mobile workers, which differs greatly between office and non-office workers, is of greater importance for occupational health and safety.

Variables which can be expected to influence working hours (occupation and occupational status, sector, tasks, decision-making power, etc.) suggest that neither eWork nor mobile eWork nor the occasional use of PSs have, in themselves, any direct impact on working hours. Rather they are used in jobs that anyway tend to be characterised by long working hours. The same conclusion may well apply to the influence of PSs on the boundary between work hours and private time, and hence on the work-life balance. Then again, the round-the-clock availability of workers due to their mobile phones or other PSs will have some degree of influence, depending on the personal behaviour of those involved. The use of profiles allocating PSs to work or to private time might help to deal with this situation. Such profiles could automatically be set dependent on time or location or other context data, such as sensor data.

If we look at other examples of accelerated technological evolution, it can easily be imagined that the development of PSs and the related ICT infrastructure will not end in the near future. Indeed, as the way work is organised changes, and tasks and activities alter, PSs will gain in importance.

"Virtual" environment issues, flexible and collaborative working practices, location-independent approaches and emerging technologies incorporated into new workplaces and

teamwork concepts will trigger new developments in the working patterns of the future. Forms of work will differ for office workers and non-office workers in the details; but in principle PS-related technologies can and will support tomorrow's work patterns in a generic way.

In the future, all workers will be connected to the Internet with some type of PS, and will use PSs, because of their micro-mobility and the need to use PSs as the gateway to the "virtual world" set up by the Internet platform of the future. The emerging Internet platform will dominate work environments and will influence all types of work and many activities and tasks.

In principle, there will be no boundary between work hours and private time because of the permanent availability of the worker and of data about his/her actual location and living context. Profiles might help to solve the problems for the work-life balance which thus arise.

PSs are designed to be portable. The main usability design criterion is the ability to support mobile people. The conflict between ergonomic criteria and portability may not be fully resolvable though a special workplace design for instant offices and work places with docking stations for mobile eWorkers at stationary points (hotels, meeting rooms, Internet cafés, other premises belonging to their or their customer's organisation, at home, on trains or planes) might help. With regard to occupational safety and health, due to the fact that future PSs will be limited to supporting communication and collaboration, wearable computers and paper-like input-output devices may be able to meet the criteria for both ergonomics and usability.

III Assessment of the OSH risks

1. Psychosocial risk factors

Summary

This part of the report aims to highlight sources of psychosocial load and strain in mobile work using portable computing and communication devices. Important stressors that have been found include the blurring of boundaries between work and family life, increases in working time, difficulties in supervising mobile employees and the feeling of the mobile employees themselves that they are insufficiently involved in the company's decisions and have poorer career prospects. These stressors may lead to increased mental fatigue, which may then have long-term consequences, such as impairment of the immune system, psychosomatic diseases, sleep disorders or cardiovascular disease. Measures to reduce mental strain in mobile workers using portable computing and communication devices include the training and preparation of these employees for self-organisation when mobile and for detecting and preventing stressors with potentially negative health consequences. Feed-back routines for the evaluation of achievement should be agreed on and employees should not be forced to be constantly available. It must also be borne in mind that the psychosocial risks which arise may differ significantly according to the specific job and sector, whether industrial or administrative.

Introduction

When considering the use of portable computing and communication devices and its psychosocial implications it quickly becomes apparent that this application creates specific working conditions that may offer a wide range of new opportunities. However, along with positive effects, such as an increase in flexibility and autonomy, potentially negative consequences may also develop for employees working under these conditions as well as for their employers. These potential drawbacks include social isolation and communication barriers.

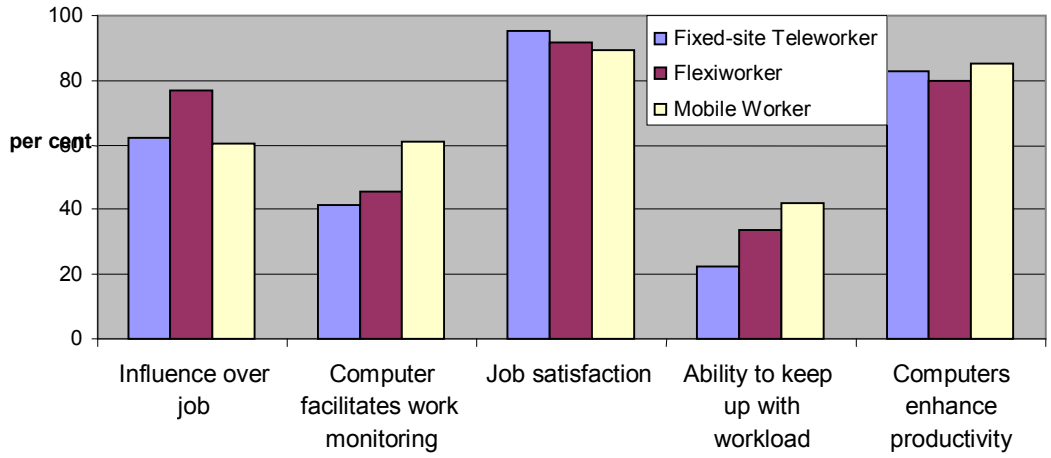
This chapter presents the results of a literature analysis and interviews with experts on psychosocial risk factors and resources for work with portable computing and communication devices. Analysing the psychosocial consequences of this type of work primarily involves an investigation into the working conditions created by the use of these devices. These specific risk factors and resources will be presented in detail in the next part of this chapter.

To date, research in this particular field has been very limited. Hislop and Axtell (2007), for example, found only three studies providing empirical data on mobile telework, a related concept of work which includes the use of portable, mobile computing and communication devices and which only recently has become a subject of scientific research. According to Daniels et al. (2001) mobile telework is characterized as work usually involving travel and/or spending time at the customer's premises, whereby people doing this work may use laptop computers, mobile phones or other mobile technical devices to support their work. Studies of mobile telework mostly concentrate on classic mobile office employees, such as managers or sales people.

However, portable computing and communication devices are also used by employees who work on the company's premises or at least within a narrow local radius, for example, drivers or service engineers. Therefore, Kohn (2006) has introduced the concept of mobile **ICT-supported work** (mobile information and communication technology-supported work) in order to include all these different users of portable computing and communication devices. Up to now, the psychosocial consequences for this wider concept have not been studied, so this part of the study has had to concentrate on the few results that have been derived from the field of mobile telework. In order to include more relevant results, other forms of work that share at least some specific characteristics with ICT-supported work were also considered. These were **home-based telework**, which also uses ICT for information exchange between the teleworker and the employer and his or her colleagues, and **flexible work**, which concentrates on flexible working-time arrangements but also on a high degree of self-organization. Especially for home-based telework, broad scientific knowledge can be found (Hislop, Axtell, 2007).

However, with respect to criteria such as influence over the job or support through ICT, these related forms of work also differ significantly from each other in terms of the resulting strain (see figure 14). Thus, when including results from these related work forms, careful consideration has to be given to which scientific results can be applied to describing the risks and resources of work using portable computing and communication devices.

Figure 14: Effects of different forms of telework from a study among members of the three groups



Source: Garrett, Danziger, 2007.

This chapter will show how specific psychosocial risk factors and resources were derived from the literature. These risk factors and resources will be assigned to different categories of stress identifiable within the work process (see Paridon et al., 2004). Additionally, the category "personal influences" is used. The categories are:

- Work organization,
- Work content,
- Social relations at work,
- Operational and societal conditions,
- Personal influences.

The specific psychosocial resources and risk factors will be investigated and individual and organizational consequences will be discussed.

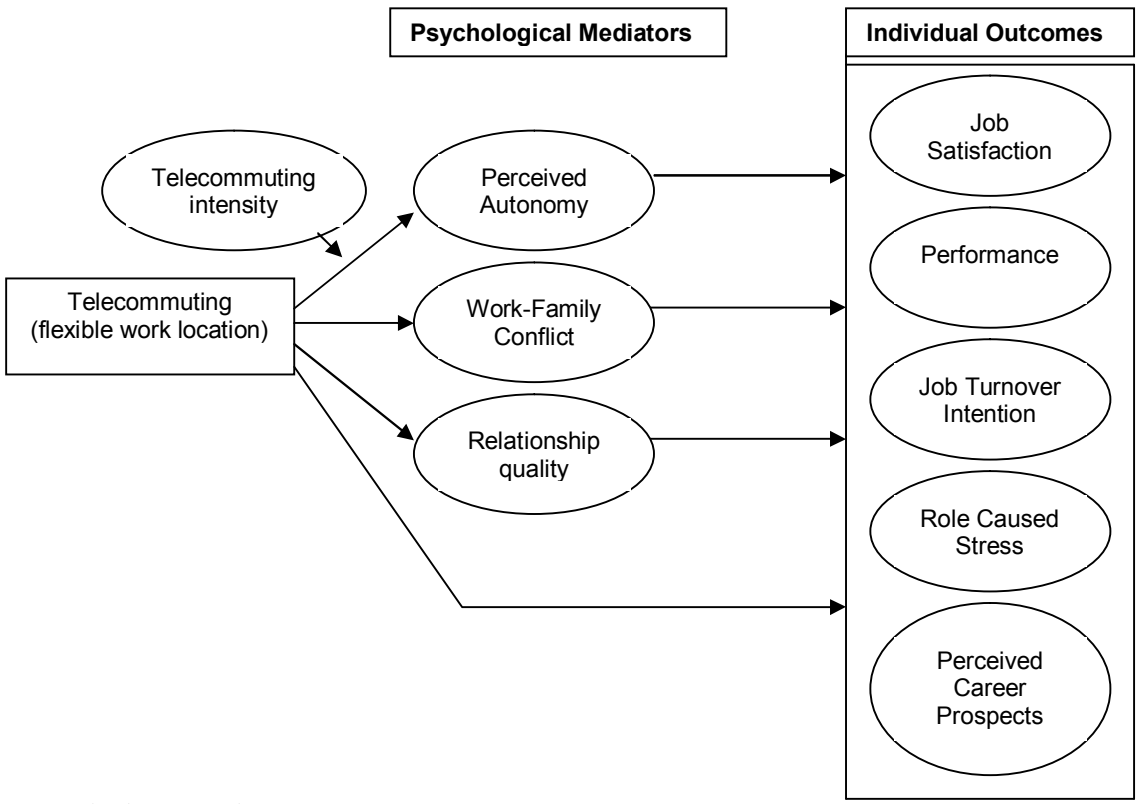
The psychosocial implications of work with portable computing and communication devices will also be considered with reference to specific illnesses or accidents caused by this form of work, future technologies, the ageing workforce and the increasing share of women in the workforce. To supplement the results from the literature analysis results from four expert interviews will be provided.

Deduction of psychosocial risk factors and resources

Salanova and Schaufeli (2000) argue that it is not mere exposure to technology per se which is responsible for health consequences, but rather mediating variables such as job characteristics or the appraisal of exposure. This general finding can be applied when looking at the consequences of work involving portable computing and communication devices as well. It is not, or at least not only, the mobile use of the technology itself that leads to positive or negative outcomes but rather the whole organizational setting and also the personal characteristics of the users. The investigation into psychosocial risk factors and resources focuses on these organizational and personal conditions while cognitive ergonomics focuses on the psychological consequences of the use of portable ICT itself, mainly including aspects of usability. These will be discussed in the next chapter.

Gajendran and Harrison (2007) developed a model to explain the psychosocial consequences of **telecommuting**, a term which may be regarded as synonymous with telework (see figure 15). They consider perceived autonomy, work/family conflict (conflict between the role at work and the role in the family) and relationship quality at work to be mediating factors in the relationship between telecommuting and individual outcomes such as job satisfaction, performance, turnover intention, role stress and perceived career prospects.

Figure 15: Theoretical framework for the consequences of telecommuting



Source: Gajendran & Harrison, 2007.

The model has been developed from a meta-analysis mainly including studies on home-based telework but also some on mobile telework. Particular relationships between these variables are proposed and have been investigated in the study. Telecommuting, for example, is positively related to perceived autonomy, which strongly influences the effect of telecommuting on job satisfaction. This means telecommuting has a positive influence on job satisfaction when autonomy is perceived. Telecommuting also has direct relations to the individual outcomes.

A substantial problem that develops from mobile telework refers to access to information as well as information input and processing (Schulte, 1999). Technical developments in this field have been substantial, as explained in chapter 1, but still mobile teleworkers often do not have the same access to work-related information, and particularly informal information, as their colleagues in the office.

Schulte (1999) and Richter et al. (2007) refer to the difficulties that mobile telework creates for the work-life balance. Both emphasize that mobile teleworkers tend to work longer and often do not effectively separate work from leisure time.

Salanova and Schaufeli (2000) found that the impact of the use of information technology on the development of burnout is strongly influenced by the appraisal and experience of the users. It should, therefore, be ensured that employees who regularly work with information technology are thoroughly familiarised with their technical devices and feel comfortable using them.

A study by Pérez et al. (2002) of a Spanish sample of different companies using telework found that the major problem of telework for the companies was management by supervisors.

Richter et al. (2007) considered the psychosocial resources and risks of mobile virtual work with a special emphasis on virtual teams. These teams included members working from very different locations with the support of mobile ICT devices and who may therefore be considered mobile teleworkers. The authors quote Sennett (1998), who points out that "mobile business structures are an erosion of the employee-employer relationship and a breakdown of the classical occupational biography". In their opinion the consequences of the change developing with mobile business structures have not yet been clearly identified but Richter et al. present scientific findings that illustrate at least some of the resources and risk factors. The workload in virtual work identified in their article refers not only to "distinct work tasks, working hours, role conflicts, or personal concerns but also to an increasing amount of necessary organizational and procedural regulations, and less contact with other colleagues".

A comparative study of virtual and non-virtual working teams by Richter et al. (2007) revealed that virtual teams exhibited more enriched job characteristics, for example, amount of organizational tasks, learning requirements and participation. Virtual and mobile work places were found to be more flexible and to require intensive interaction with ICT tools.

Richter et al. (2007) also mention the difficulties arising from mobile virtual work in the areas of **collaboration** and **motivation**. These aspects are also investigated in a study by Schulte (1999). Schulte introduces communication problems in mobile work within the frame of the transaction cost model (Coase, 1937 in Schulte, 1999). The model refers to costs that arise from the need to coordinate economic relationships, for example, searching for information about future contract partners, contract negotiation or supervision of finalising contracts. This

coordination is naturally more difficult and produces higher costs when the partners have to communicate via ICT so the model may be applied to work using portable computing and communication devices.

Motivation in this study is considered from two different perspectives. On the one hand, the mobile-working employee may be motivated to opportunistically abuse the information asymmetry towards the supervisor which arises from their significant autonomy by not transferring important information or not working the agreed amount of time. On the other hand, the study also shows how mobile ICT can negatively influence the intrinsic motivation of the mobile worker through a feeling of supervision and control due to permanent availability.

The psychosocial resources and risk factors involved in the use of portable information technology at work mentioned in this introduction are combined in table 8. Variables from a comparison by Pyöriä (2003) containing more positive and negative aspects of distributed work, a form of work also sharing the main characteristics of mobile telework, are added.

Table 8: Assignment of resources and risk factors to forms of work load

Resources	Risk Factors
Work Organization	
Flexibility	Working time: higher quantitative work-load
	Communication barriers
	Reduced information access and processing
	Work-life balance
	Permanent availability
Work content	
Autonomy/Increased freedom of action	
Job enrichment	
Social relations at work	
	Lack of social support and isolation
	Limited possibilities for supervision and leadership difficulties
Operational and societal conditions	
	Work place insecurity
Personal Influences	
	Ability to self-organize

The above-mentioned categories with their risk factors and resources will be investigated in the following section, which describes specific health and accident risks. As working conditions in work using portable computing and communication devices can differ significantly between individual workers, this review can only give a general insight into resources and risk factors. Nor are the variables perfectly disjunctive. This fact may lead to some overlaps or small repetitions in the results of the investigation. Furthermore, it must be stated that the assignment of a factor as a resource or a risk factor is generally not unambiguous. Most of the factors found may influence mental health positively or negatively depending on their specific design and intensity in a particular work situation. This will become obvious in the next section.

When considering telework in general and work using portable computing and communication devices in particular, it should be borne in mind that the employees are mostly not full-time teleworkers as they also do part of their work at the company's premises.

1.1 Investigation into specific psychosocial resources and risk factors

1.1.1 Work organization

Flexibility

Flexibility as a whole cannot be judged good or bad. The consequences for work organization and health in particular largely depend on arrangements decided between the employer and the employee, as has been found by the Risk Observatory on emerging psychosocial risks (European Agency for Safety and Health at Work, 2007). A study by Martinez et al. (2007) comparing companies using and not using different forms of telework concludes that teleworking may develop its full potential when it is implemented together with other flexible workplace practices (flexitime, variable payment, etc.).

According to a report by Broughton (2007), 83% of workers who combine work outside the company's premises with work at home say that they can change the order of their work tasks. This compares with 60% for those whose work is company-based. 51.1% of workers who work away from the company's premises (mobile teleworkers) stated that they do not have fixed starting and finishing times. A study by Paridon and Hupke (2008) confirmed these results, showing that 77% of a sample of mobile teleworkers investigated could often or always organize work flexibly.

The figures illustrate the fact that the flexibility of non-company based workers is generally higher than that of workers based on the company's premises. A longitudinal study by Konradt and Schmook (1999) confirms these results for home-based teleworkers, particularly with regard to work time flexibility.

High levels of flexibility are evaluated positively by mobile teleworkers while low levels less often receive positive evaluations (Paridon & Hupke, 2008). Flexibility may equal control and increase the perception of autonomy (Hackman and Oldham, 1976), so higher levels of flexibility may increase work motivation and job satisfaction (Gajendran and Harrison, 2007) especially for knowledge workers who are capable of the amount of self-organization required.

However, the increased need for self-organization that arises as a consequence of increased autonomy may also be a source of increased stress, especially for those workers who are not used to higher amounts of self-organization. Training should ensure that these workers are well prepared for the working conditions which evolve from work using portable computing and communication devices. To the author's knowledge, the likely relationship between the evaluation of flexibility and the ability to self-organize has not yet been studied.

Working time may be organized very flexibly and offer the potential for a better work-life balance. Still, for a significant number of working people regularity in working time is more important than flexibility when their private commitments are considered (European Foundation for the Improvement of Living Conditions, 2007). Work time flexibility may, therefore, appear to be an advantage of mobile work, but the employees themselves might not

regard it as such and prefer to retain regular working times. The higher flexibility of mobile workers may also generally support the work-life balance, as private duties may be fulfilled more flexibly. This may help to reduce feelings of stress. Conversely, boundaries between work and leisure time may be blurred (Mann & Holdsworth, 2003) by working evenings or weekends or in between leisure activities.

Goudsward and de Nanteuil (2000) state that flexible employment strategies in most cases lead to a lack of control over working time. Martens (1999) shows that flexible work schedules are positively correlated with health complaints and a general decrease in well-being. The study does not concentrate only on mobile workers but also includes shift and temporary workers so that it is not completely clear if these results can be extrapolated. However, the relationships presented stress the importance of further investigation into the results of flexible working times for mobile workers.

It is important to distinguish between forced and freely-chosen flexibility. While freely-chosen flexibility has generally positive consequences for employee health, forced flexibility may, according to the Risk Observatory on emerging psychosocial risks, result in a decrease in psychological and physical well-being (European Agency for Safety and Health at Work, 2007). Mobile teleworkers may differ in that respect as well, in view of the particularly high strain for on-demand mobile teleworkers.

Flexibility for employees using portable computing and communication devices also means flexibility in the place of work. This includes the need to search for appropriate places to use mobile technology, for example, flat surfaces for laptop-use or quiet places for telephone calls. Searching for such places together with a feeling of insecurity as to whether technical devices will work properly (for example, whether a mobile telephone connection is available when urgently needed) may also induce increased levels of stress.

Changes in working time

In the general telework literature there is much data that supports the view that working away from the company's premises leads to an increase in working time, as figures from several European countries show. Dutch teleworkers work 46 hours a week on average while non-teleworkers only work 39. Many of these workers are not eligible for overtime pay. In France, a study by the National Institute for Statistics and Economic Studies (Institut National de la Statistique et des Études Économiques, INSEE) over the period 1999 to 2003 found that teleworkers commonly reported working at night and on weekends. 20% stated that they regularly worked between 10 p.m. and 6 a.m., compared with 10% of other employees (Broughton, 2007). It may also be assumed that teleworkers do not regularly take breaks, as there are no external prompts to remind them. A permanent lack in recovery time can lead to increased risks of cardiovascular diseases (Martens et al., 1999).

According to Richter et al. (2007) the work of virtual teams consists of longer work cycles. They state that often there are high expectations of virtual teams as they are supposed to be experts. There may be pressure to work longer and provide the best possible results as a result of this expectation.

Many mobile workers spend a considerable amount of time travelling, but the time they actually spend on trains or other means of transport is not fully recognized as working time (Weber-Bensch, 2005). Such company policy may cut significantly into leisure time.

Communication barriers

Electronic communication does not yet and probably will never fully match the richness of face-to-face communication. Mulki et al. (2008), for example, report study results showing that e-mail contact generally lacks the richness and social presence associated with face-to-face dealings. Nor can increased communication via email fully replace face-to-face or telephone communication.

When considering mobile phone use it is important to be aware of the social context surrounding it. Often mobile phone users are not alone during calls or find themselves in places where telephoning is not appropriate, such as in trains, restaurants or libraries (Hislop & Axtell, 2007). This situational component may induce stress.

Andres (2002) proposes two criteria that can help to structure the advantages and disadvantages of electronic communication: **social presence** and **media richness**. Media richness refers to the existence of verbal cues[76], facial expressions, gaze, gesture, posture, physical proximity and back-channelling cues[77] in communication. The lower this variability is, the more uncertainty and ambiguity may arise and complicate communication processes. Social presence refers to a feeling of being jointly involved in communication and feeling the presence of communication partners. Past research has identified a continuum for social presence ranging from e-mail, teleconferencing and computer-desktop conferencing to face-to face communication.

A lack of social contact cues may lead to an increasingly negative communication tone that includes assertive or hostile language and an increased sense of depersonalisation (Siegel et al., 1986, Sproull & Kiesler, 1986). On the other hand, asynchronous work-groups (work groups who work on tasks at different times and not together) experience greater productivity (Ocker et al., 1996), especially when there are no time constraints and interdependence of tasks is low. However, when time constraints and task interdependence increase, the productivity of virtual teams falls below face-to-face groups. Thus the context of electronic communication plays an important role in productivity.

With regard to the health and well-being of employees using portable computing and communication devices, it can be stated that decreases in productivity and increases in effort in order to maintain effective information exchange may lead to uncertainty and ambiguity, which in turn may increase stress levels.

However, a study among human resources experts by Pérez et al. (2002) found that communication problems were not perceived as important barriers to the implementation of telework. This may indicate a difference in the perception of the consequences of telework between the management and the workers themselves.

Pyöriä (2003) emphasises the fact that tacit or implicit knowledge is very difficult to acquire in mobile telework. Tacit knowledge refers to a concept by Polanyi (1966). It is knowledge which is not explicitly formulated and often not explicable but rather can be acquired by observing experts working or by longer discussion. This might, for example, be the case when a mobile worker seeks information from an expert located at the company's premises which is difficult to explain in words, e.g. information on certain computer routines or customers. This kind of knowledge is very difficult to transfer by phone or other means of electronic

[76] Accentuation or emphasis of important contents e.g. by repetition, speaking louder.
[77] Expressions indicating that the listener is following the speaker, such as "Oh" or "Mm".

communication. Hardill and Greene (2003) also conclude that face-to-face contact and inter-organisational transfer of employees are still crucial elements in knowledge transfer.

Meyer et al. (2007) report problems of virtual collaboration such as a lack of opportunity to contact supervisors to coordinate work immediately. Therefore, mobile workers should be given a high degree of involvement in decisions and the task design should be considered in more detail, especially regarding job demands and decision latitude.

In virtual teams conflicts are often detected too late. It is therefore recommended that efficient communication and collaboration processes be implemented to prevent misunderstandings and conflicts (Hertel et al., 2005). It is also important to structure the details of the work, for example, tasks and timelines. These tasks should be led by supervisors.

Reduced information access and processing

Technically supported communication may cause certain indirect costs, such as a loss of time or of important information. To structure costs that may arise due to electronic communication, Schulte proposes the use of the Transaction Cost Model by Coase (1937, in Schulte 1999). A transaction cost is a cost incurred in making an economic exchange. Transaction costs mainly refer to information and communication costs that are necessary for the coordination and reconciliation of economic relationships.

According to Schulte (1999) specific problems for information access and processing arise from mobile telework. Costs may arise from the search for, and acquisition of, information needed for a certain work process. In a mobile setting such processes become more complicated as the employee sometimes cannot access company information. Increasing opportunities for online data exchange may reduce these costs and also the mental strain accompanying it over time. Yet it remains doubtful whether technical developments will be able to fully eliminate these costs.

The location of a mobile employee at any given time is often unclear. This creates uncertainty, especially in cases when expert knowledge or particular information is needed quickly. The cost of initiating contact rises in such situations along with feelings of uncertainty on the part of colleagues and supervisors on the company's premises, as the onus to make contact lies with the employee.

Possibilities for information input and processing are increasing with the development of new technical devices and ways to transfer information online. However, a great deal of information is still first recorded on paper and later transferred when employees work online. These tasks increase quantitative work load and may lead to stress and fatigue.

Information overload

While a lack of important information may cause insecurity and stress, workers may also suffer from an overload of information provided through their mobile portable devices. In the study by Paridon and Hupke (2008) 58% of the workers indicated having feelings of often or always being overloaded with information. About 50% of all participants said they often or always receive useless information. It may be assumed that this useless information accounts for a significant part of information overload. Companies therefore should try to specifically reduce this source of overload and simultaneously give mobile ICT supported workers the means to store and pass on important information in such a way that it can be administered easily.

Blurring of boundaries between work and private life

The work-life balance is considered to be influenced positively by home-based telework, particularly by high flexibility. Mobile ICT workers, in contrast, only rarely work at home, so their work-life balance is more comparable with that of those working permanently on the company's premises. However, for many mobile employees there might be opportunities to at least sometimes arrange work and private life according to their needs.

As in home-based telework problems may arise from the fact that portable computing and communication devices are always accessible and so employees might also work during evenings or weekends. However, this assumption could not generally be confirmed by data from Hupke and Paridon (2008). 55% of mobile workers in this study said they never or only rarely face blurring of boundaries between work and private life.

Hislop and Axtell (2007) point out in their study that huge differences exist between employees with low and those with high levels of discretion. While low discretion workers such as service engineers normally just work locally and need to be mobile within a radius of a maximum of 20 kilometres, high discretion workers often have to travel long distances and stay away from home for several nights. These characteristics lead to huge differences when referring to the relative work-life balance of the employee groups. High discretion workers' mobility generally had a negative impact on their work-life balance while for low discretion workers the opposite was true.

In contrast to home-based workers, who face stress related to work-life balance when they cannot reconcile work and family life, it is the regular absence from home that causes stress in mobile high discretion workers in this area.

In a study by the Confederation of German Trade Unions (DGB) among 512 mobile and 1,194 company-based employees (Fuchs, 2008, Brandt & Brandl, 2008) mobile workers said that the incompatibility of work and family is one of the most negative aspects of mobile work.

Permanent availability

60% of mobile employees studied by Paridon and Hupke (2008) reported that they always or at least often have to be available for colleagues and supervisors. Being available at all times bears the risk of blurring the boundaries between work and private life and therefore

decreases the work-life balance. This applies especially to staff with supervisory responsibilities and self-employed workers, as reported in the Fourth European Working Conditions Survey (European Foundation for the Improvement of Working and Living Conditions, 2007). It also increases disturbances in work flow.

In her study on mobile work Weber-Bensch (2005) found that permanent availability is considered a negative strain factor by many employees and the feeling of permanent control that may arise is related to reduced well-being.

Permanent availability also increases the quantity of communication processes, but at the same time often lowers their quality and disturbs work-flow significantly. In the U.S. the new field of "interruption science" is being developed. This deals with the consequences of permanent availability and the interruptions caused by it. Studies in this field have found that every interruption is connected with a rise in heart rate and skin conductivity which are indicators of an increase in stress (Dörner, 2008).

1.1.2 Work content

Autonomy/Increased freedom of action

Autonomy is considered a key mediating factor in the model by Gajendran and Harrison (2007) of the consequences of telecommuting (see figure 15). It significantly influences the relationship between telecommuting and job satisfaction, turnover intent and role stress. Telecommuting is positively correlated to these three variables when autonomy is given to the mobile worker. A study by Martens (1999) on different flexible workplaces found that job autonomy is negatively correlated with health complaints and a decrease in well-being, indicating that autonomy generally has a positive influence on physical and mental health at work.

However, autonomy may also involve risks. From the employer's perspective a lack of opportunities for supervision may lead to doubts as to whether employees are correctly fulfilling work requirements or taking advantage of their increased freedom of action. Additionally, the employee may sometimes be unsure about how to make decisions in certain situations, compounded by the fact that an increase in autonomy increases the number of decisions to be taken. Autonomy may thus lead to mobile employees suffering from higher insecurity and mental strain.

Therefore, mobile work should be the subject of clear agreements between employer and employee (Pyöriä, 2003). These agreements should be evaluated carefully by both parties as autonomy is sometimes diminished when telecommuting employees have to sign very detailed agreements specifying work in much more detail than is actually needed. On the other hand, a certain degree of specification may generally be very helpful for the employees.

Work enrichment

Work enrichment in virtual work is discussed by Richter et al. (2007). For example, they state that in virtual teams more organizational tasks and functions are transferred to the group members, that the group organises work by itself to a greater extent, members face significantly more learning demands and responsibilities, and that they are more involved in

planning processes. Higher levels of stress and lower levels of fatigue were observed in virtual teams.

This corresponds to the findings of Montreuil and Lippel (2003), who also state that enriched jobs create more stress. There are associations proposed between levels of stress and different aspects of work which include organizational demands, increased responsibility, increased amounts of cooperation as well as rising sequential completeness (work tasks including different steps from planning to organization, execution and evaluation). Richter et al. (2007) propose a curvilinear relationship between job enrichment and stress according to the Vitamin Model (Warr, 1987) stating that too many or too complex tasks may have similar effects on the development of negative mental strain, as does too little variety of tasks.

1.1.3 Social relations at work

Social support and isolation

According to European research, employees that work away from the company's premises may suffer from a lack of contact and social support from their colleagues and supervisors. This may be even more difficult for lower skilled workers as they often do not take part in regular team meetings (European Foundation for the Improvement of Working and Living Conditions, 2007). Data from the European Working Conditions Survey (2005) shows that when employees were asked whether their job involved exchange of communication and working materials or results, 80.1% of people who work at home, including teleworkers, stated that their job did not. Likewise, 74.2% of those combining working away from company's premises and work at home stated that their job did not involve these kinds of exchange, and 64.8% of those working solely outside the company's premises gave the same answer. This compares with 52.4% of those working on the company's premises.

With regard to isolation in mobile telework, the research shows mixed results (Mulki et al., 2008). Mann and Holdsworth (2003) report from their study on home-based teleworkers that 67% of respondents said they at least sometimes suffer from loneliness at their workplace. Mulki et al. (2008) report results from different studies, such as the feeling of being left out due to a lack of personal contact, loss of camaraderie and little chance for informal meetings and exchange (non-company-administered information exchange between employees). They also mention deprivation of career support, mentoring and a feeling of having worse chances of being involved in major projects. Two different types of isolation, company and colleague isolation, are suggested. Company isolation refers to the employee's feeling of not receiving enough career-based support and mentoring from supervisors and the organization in general. It is negatively correlated to organizational commitment. Low organizational commitment may then lead to decreased quality of job performance.

However, telework does not necessarily lead to feelings of isolation and separation from colleagues and supervisors. A study by Gajendran and Harrison (2007) found no negative consequences of telecommuting on the relationship to colleagues and even positive consequences for the relationship to supervisors. A recent online survey among mobile teleworkers by Paridon and Hupke (2008) found that most of the participants have possibilities for social interaction and receive social support from colleagues during their work and evaluate these opportunities positively. As many mobile teleworkers have regular face-to-face contact with customers when away from the company's premises it may be

assumed that for this group of employees, isolation is less of a problem than for home-based teleworkers.

To prevent feelings of isolation regular meetings may be necessary. Teleworkers should be encouraged to take part in important company events and there might be fixed times when the employee is required to work in the office, for example, one day per week. Some companies also use regular virtual team meetings or virtual team work to give teleworking employees the feeling of being integrated (European Foundation for the Improvement of Working and Living Conditions, 2007).

Possibilities of control: supervision/leadership

The task of managing employees with portable computing and communication devices is very different from managing office-based workers. As the possibility of direct supervision is generally either small or non-existent when only little time is spent on the company's premises, other ways to ensure support, mentoring and supervision must be utilised.

One factor being studied in this context is the importance of trust between employer and employee. Mulki et al. (2008) report studies which found that trust increases an employee's ability to cope with organizational stressors, fosters organizational commitment and enhances job satisfaction. In virtual working conditions trust is especially important as supervisors generally do not have direct control over their teleworking employees. Trust can be increased by creating more opportunities for communication and informal networking, for example, through regular meetings or the implementation of regular office work days.

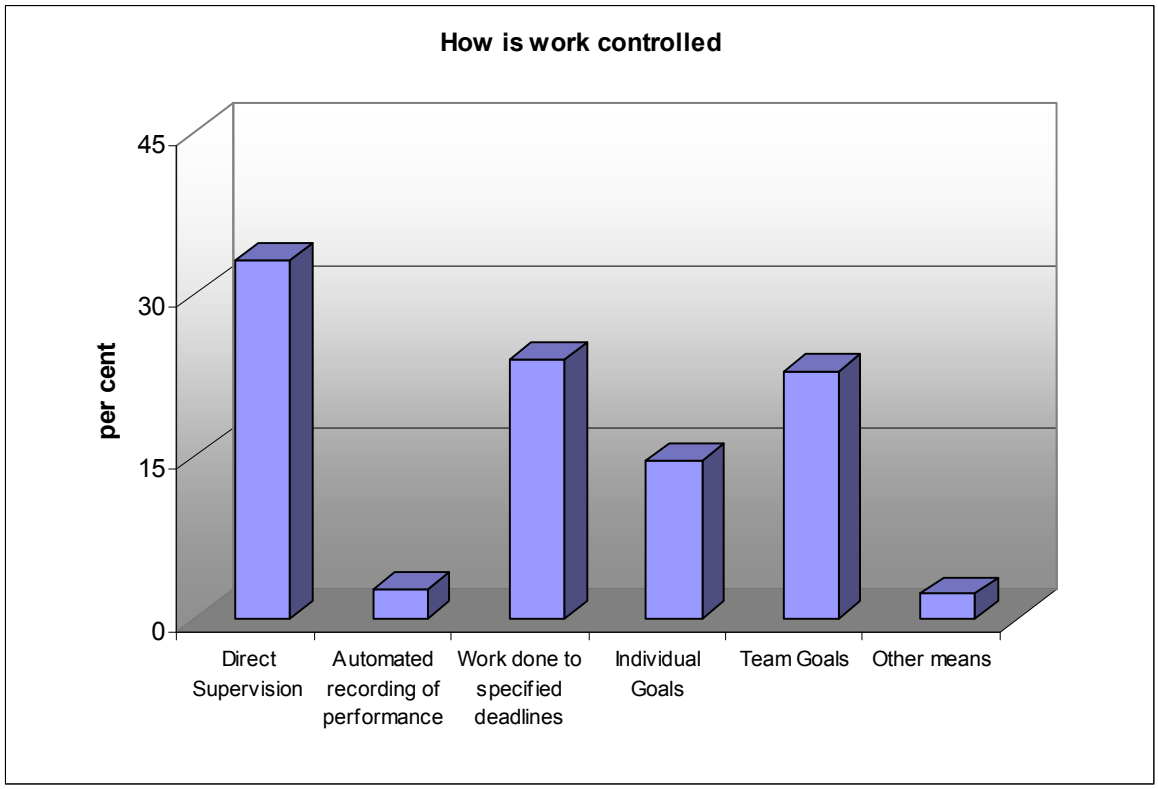
Telecommuting can even lead to feelings of an improved employer-employee relationship as shown in a study by Gajendran and Harrison (2007). Trust might play a very important role when these relationships develop in such positive directions.

Supervisors also have to be aware that employees can face problems when operating as mobile teleworkers. For example, it has been found that salespeople in remote offices needed their supervisor's help to impose structure on their daily activities (Mulki, 2008). Employees working in a mobile mode for significant amounts of time should, therefore, be well prepared for what to expect and their work should be discussed with their supervisor regularly. This, of course, largely depends on the position and the abilities of the mobile worker.

There is consensus that telework in general can only be effectively realized with leadership that makes use of management by results or objectives (Illegems et al., 2001, Hörmann, 2000). In mobile work, goals such as time limits may help workers to structure their work, which might otherwise be too long or too much (Richter et al., 2007). The goals agreed on make it easier for the employer or supervisor and the employee to know each others' expectations and capabilities, especially when large parts of working-time take place outside of the company's premises. Thus goal setting also serves as a control measure.

Figure 16 shows results from a survey conducted by Clear and Dickson (2005) explaining how work is controlled in a sample of 300 small and medium-sized enterprises in five European countries. They suggest that companies practising direct supervision would first need to introduce other methods of control before introducing telework.

Figure 16: Different forms of control in small and medium-sized enterprises



Source: Clear & Dickson, 2005.

However, technical opportunities for direct control in telework also exist, such as a permanent demand for data transmission, time sheets or even the use of Global Positioning System (GPS) to trace employees' movements (Broughton, 2008). Working times and the contents of technical devices could also be recorded or telephone calls might be traced. However, these activities decrease the employee's freedom and may destroy feelings of trust for the mobile teleworker. A lack of intrinsic motivation will most likely develop from such measures, so careful consideration must be given to the necessity of such measures and whether they are more important than the intrinsic motivation arising from greater freedom of action (Schulte, 1999).

Supervisors also have to make sure that the work of their teleworking employees is evaluated and that they receive feed-back and reward in the same manner as office-based workers. These employees should have the feeling that they are considered for important assignments and that their achievements are reported to upper management lest they face the risk of a gratification crisis as proposed by the Effort-Reward-Imbalance Model developed by Siegrist (1996). According to the model, employees face an increased risk of physical or mental ill-health when significant effort at work is not rewarded adequately. It is also important to involve mobile teleworkers in company decisions. Generally mobile teleworkers evaluate having a voice in company matters as positive while those who are not involved in company decisions evaluate this negatively (Paridon & Hupke, 2008).

1.1.4 Operational and societal conditions

Work place insecurity

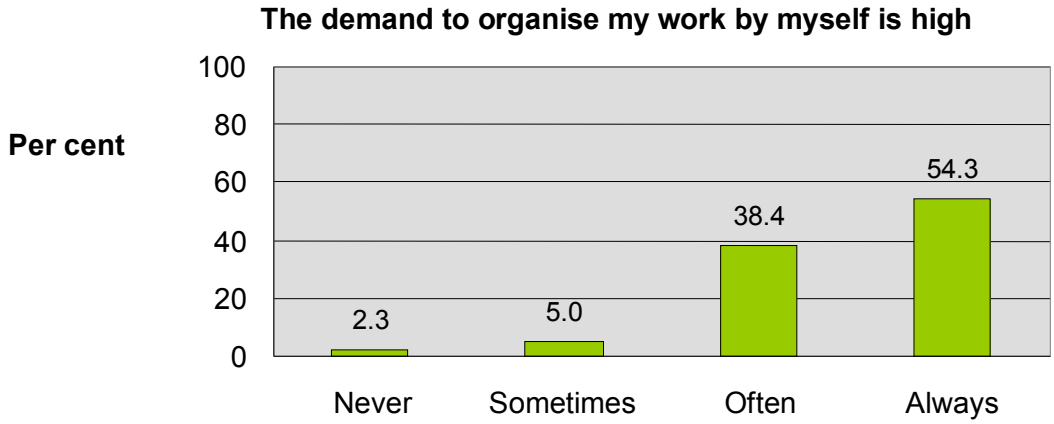
In a study by the Confederation of German Trade Unions (DGB) (Fuchs, 2008, Brandt & Brandl, 2008), mobile workers reported higher feelings of job insecurity. The reasons for this higher insecurity have not yet been clearly identified but high stress levels may lead to a perception of not being able to carry on under the prevailing working conditions until retirement. Also a lack of access to informal information as previously described might give employees the feeling that their work is not being sufficiently appreciated.

1.1.5 Personal influences

Employee characteristics

Mobile telework places special demands on the employee. As mobile teleworkers mostly have to structure their work days and arrange appointments on their own, an ability to self-organize is essential (figure 17).

Figure 17: Answers from mobile ICT users



Source: Paridon & Hupke, 2008.

Employees applying for a mobile position should, therefore, be carefully selected. They should also be thoroughly informed regarding what to expect and questioned as to whether the autonomous, self-organized working style necessary for such positions is compatible with their way of working (Hörmann, 2000).

The employees should also be introduced to the psychosocial risk factors arising from mobile work and be enabled to handle specific stressors. Relevant training for the employee as well as for the employer is therefore important when mobile work using portable computing and communication devices is introduced in a company.

Employees must also be able to cope with longer periods of isolated working, an ability which largely depends on the personality of an employee. This aspect should be discussed thoroughly as an inappropriate deployment might even result in depression.

1.2 Risks of illness and accidents deriving from psychosocial stressors

The stressors described in the previous section generally have the potential to cause not only stress but also other forms of negative psychosocial strain, such as fatigue or mental saturation. When chronic, over months or years, these strain factors bear the risk of causing illness. The illnesses that are primarily discussed in relation to psychosocial stress are coronary disease (Öhlin et al, 2004), back pain, sleep disturbances and impairment of the immune system (Jones & Bright, 2001). These observations are supported by theoretical models such as the above-mentioned Effort-Reward-Imbalance Model developed by Siegrist (1996) and the Vitamin Model developed by Warr (1987). The latter model proposes nine psychosocial stressors, some of which may have a negative impact on health in excessive doses, as in the case of vitamins A and D. Examples of such negative impacts are: control opportunities, variety of work tasks or interpersonal contact. Other psychosocial stressors may not be harmful to health even when present in very high doses and thus comparable with vitamins C and E. Examples of such factors are physical safety and social status.

Accidents caused by psychological stressors are mainly the subject of cognitive ergonomics and will be discussed in the next chapter. Of course high levels of psychosocial stress may lead to a lack of attention and therefore increase the risk of an accident. Up to now there seem to be no data regarding the frequency of illnesses and accidents specifically among mobile workers.

1.3 Psychosocial implications for the proposed future development in work using portable computing and communication devices

From a psychosocial perspective, a major concern for the future development of portable computing and communication devices is its spread, which forces more and more employees to work at least partially in a mobile mode and which is connected with the above mentioned risk factors. When companies increase the number of mobile staff they will have to recruit them from a pool less obviously suited to the task and must therefore take greater care when choosing and preparing these employees for this type of work. Companies also must reconsider their management and communication strategies in general and adjust them for mobile work.

New technical developments may bring opportunities as well as risks. Virtual communication techniques which offer ways to communicate which are very similar to real face-to-face communication may be applied to facilitate information exchange. Moreover, having been accustomed to it from an early age, the younger generation may view technical means of communication more positively and therefore experience less difficulty and strain when communicating virtually in their future jobs. On the other hand, the workers and their work may be monitored by technical equipment, which may be assessed negatively. New technology can also overstrain its operators when it is too complicated. On the other hand, devices which are designed ergonomically will facilitate work.

1.4 Demographic effects

The psychosocial consequences of work with portable computing and communication devices and the ageing workforce

As mentioned in the introduction to this chapter, there is only a very small amount of scientific research into the psychosocial effects of mobile telework. The specific consequences for older mobile teleworkers have been investigated even less. The advantages and disadvantages of mobile ICT for older workers are discussed by Charness (2006). These include decreases in specific cognitive functioning such as speed of perception and short-term memory. As these factors refer to aspects of usability they will be covered in the next chapter.

However, no explicit reference is made to specific psychosocial outcomes for mobile telework so only general experiences can be reported. The Risk Observatory of the European Agency for Safety and Health at Work (2007) states that in older workers several decreases in ability are countered by certain increases. Some of these results can be transferred to mobile telework. For instance, older people are more independent in their decision making and have more experience in their work, which increases their ability to work autonomously. This may even result in lower stress levels due to task insecurity than in younger workers. It is also reported that older people have a greater sense of responsibility and duty, which may help to establish trust and an efficient exchange of information between older mobile teleworkers and their supervisors. Older people can generally also assess their abilities and limitations more realistically. Thus in mobile telework they might be better able to structure their working days according to their needs and abilities and not overstrain themselves.

Older mobile teleworkers reported significantly less support from colleagues than did younger mobile teleworkers (Paridon & Hupke, 2008). It can be assumed that these older workers are more reluctant to ask others for help, which would generally be a disadvantage for mobile work.

From a psychosocial perspective there is no reason to believe that older workers are generally less suited to mobile telework.

The psychosocial consequences of work with portable computing and communication devices and the increasing proportion of women in the workforce

From a psychosocial perspective women may experience higher stress in mobile telework when they are also the primary care giver in a family. This is still very common even in Western European and American families where fathers generally do not engage as much in child care and external child care is still rare and expensive. If women do mobile work they may suffer from mental stress that develops from organizing child care during their absence and worrying about their children's well-being. Family duties are probably one of the main reasons why women are underrepresented in mobile telework involving staying away from home overnight. Another reason is the fact that the majority of mobile teleworkers who stay away overnight are managers or professionals (Garrett, Danziger, 2007), still categories where women are underrepresented.

1.5 Expert interviews

The expert interviews are intended to supplement the results from the review of literature with practical findings from the work of experts on projects concerning work with portable computing and communication devices. The following experts answered questions in a standardised interview.

Cornelia Brandt works for Ver.di, the German trade union for the service sector. She started to investigate the consequences of telework in the nineties and then shifted her focus to mobile work. She has worked in several projects on the topic (OnFormA, PaPsD, Index "Gute Arbeit").

Pekka Huuhtanen is a research professor and team leader at the Finnish Institute of Occupational Health: Work Organizations Changes and Future Work. Since 1995, he has been the coordinator of a European project on health and safety in telework covering 15 EU Member States. Two articles by him on telework and eWork have been published on the website of the European Agency for Safety and Health at Work.

Dagmar Siebecke is a scientific project leader at the Faculty of Business and Social Sciences at the University of Dortmund (Germany). She took part in a project co-financed by the European Union and the German Ministry for Education and Science. The project is called PRAGDIS and aims at collecting scientific knowledge on occupational safety and the prevention of disease in discontinuous career histories. One form of work being investigated in the project is mobile work.

Piet van Lingen and Friso van der Meulen work at TNO Hoofddorp, in the Netherlands. They have worked on mobile data terminals in police cars and the project "Distance Working", a four year research program that started in 2003.

Additional results

Many risks and resources named by the experts confirmed the results from the literature and will not be quoted again. Particular risks such as social isolation, lack of supervision and leadership, increased work load and intensity and work/family conflict were named. The following aspects mentioned by the experts have not been considered in the literature analysis.

When employees do mobile work they may have, and take, fewer opportunities to delegate tasks to specialized colleagues and thus be forced to work more than office-based colleagues to fulfil such tasks. Examples of this are correspondence with clients, processing of data or the search for particular information requested by a customer.

If the level of mobile work in jobs increases in the future there is the risk that work-family conflicts will increase. Parents, especially, will have great difficulty taking care of their children when both mother and father have jobs that require mobility, especially when this includes staying away overnight. The topic has not yet been a subject of intense discussion. The question is whether employers should be encouraged to assist employees to continue working by providing the opportunity for in-company child care. Working times could be arranged according to the needs of employees with children. It could be argued that a solution is best left to the employees themselves but apart from increased stress levels and financial

demands for child care this might lead to a lack of equality. If one parent is forced to quit the job, it is highly likely to be the woman in accordance with current gender roles. Therefore, official regulations or at least recommendations might be a solution.

Mobile work using portable computing and communication devices not only bears the risk of longer working hours but may even lead to workaholism.

It has also been observed that due to lack of time, supervisors discuss topics with their mobile employees on the phone or per e-mail which would be better discussed in a face-to-face situation. Typical topics of this nature are employment contracts and other personnel matters.

It was also suggested that mobile workers should receive more support from transport companies when they work while travelling. For example, companies could provide more lounges with higher seating capacities in stations and airports.

It is expected that the concepts of "just-in-time" production will be transferred to the service sector because of pressure to meet customers' needs and be available for customers at short notice. This will increase the demand for faster work and put higher levels of strain on mobile employees.

1.6 Conclusions

Generally, there has been little scientific research on work using portable computing and communication devices. However, by taking knowledge and experience from related forms of work it is possible to identify the main psychosocial risk factors and resources. The main sources of strain in this kind of work are factors arising from work organization such as flexibility, working time, communication barriers and the work-life balance. In accordance with this result, measures to improve working conditions and lower psychosocial risk should concentrate particularly on this field, without losing sight of other factors which may also be important.

The employer and the organization appear to have significant influence on the working conditions of their mobile employees even if they only rarely supervise them directly. In general, the effect of psychological factors often depends on their degree. Where factors may have either a positive or a negative effect, working conditions should be designed to ensure positive consequences.

The diversity of mobile work is tremendous and this should be considered when psychological factors are investigated. It may, for example, make a considerable difference whether someone works as an employee or is self-employed.
The following recommendations for the prevention of risks in work using portable computing and communication devices can be derived from the study:

- It should be ensured that, when starting to be mobile for a significant part of their work, employees are able to organize themselves and their workload.

- Employees should be introduced to the main psychological risks of mobile work and be trained to detect, and if possible handle, psychosocial stressors.

- Employees should have regular opportunities for face-to-face contact with their colleagues and supervisors to exchange information.

- Management by objectives has proven to be a very helpful approach to the supervision of mobile workers.

- Employees should have the possibility to take breaks from permanent availability.

- Employees should learn about the risks of being permanently available and learn to take breaks where possible.

- Employees should be thoroughly familiarised with their technical devices and have constant access to technical support.

- Employees should receive regular feed-back on their achievements.

- A trusting relationship should be established between supervisor and employee before mobile work is begun.

- The employee should always have the possibility to delegate tasks to colleagues at the company's premises to prevent overload.

- The problem of child care should not be seen as a solely private matter. Both companies and politicians should discuss possible support.

2. Ergonomic risk factors

Summary

This chapter deals with task 2b of the study (assessment of the OSH risks – ergonomic risk factors) and analyses the literature on the following subjects:

- Manual handling issues due to the compromise that must be accepted in terms of usability when designing portable devices and bearing in mind that they will sometimes be used in cold environments or situations that result in poor posture;
- Repetitive movements, especially involving pinch-grip, which may lead to repetitive strain injury;
- Poor visual interface due to small display screens and controls, together with problems arising from reflective glare or an insufficient level of ambient light;
- Excessive noise levels due to high volume settings to compensate for background noise;
- Static and/or poor posture due to the use of the devices in an unsuitable environment;
- Cognitive load resulting in a risk of accident – e.g. when driving or as a pedestrian crossing the road.

The analysis also includes an explanation of how the literature search was conducted.

On the basis of the data found, no thorough assessment of the above mentioned risk factors can be provided. It is possible only to make assumptions regarding their impact and to identify and highlight fields of interest for further research. Wherever information is available, the contexts of an ageing workforce and greater participation of women is considered. In addition, as far as the data analysis allows the review addresses the question of how the nature and extent of these risks will change with possible developments in the technology and its use.

Introduction

After a brief description of the variety of types of portable systems presently in use, this chapter gives an overview of current research into the hazards presented by these systems and the risks of ill health and accidents for workers. To this end, an analysis of publications was conducted, involving various types of database. For the web search a set of search engines were used (see table 9). In addition, the in-house database ZIGUV (Zentrales Informationssystem der Gesetzlichen Unfallversicherung) of the DGUV (German Statutory Accident Insurance) and the FIZ-Technik databases TEMA and INSP were searched.

Table 9: Search engines used for the web search

Google	http://www.google.de
Yahoo	http://www.yahoo.com
ScienceDirect	http://www.sciencedirect.com
Ergoweb	http://www.ergoweb.com/news/detail.cfm?id=1672
Scirus	http://www.scirus.com/srsapp/advanced/index.jsp?q1=
NetbibWiki	http://wiki.netbib.de/coma/AufsatzRecherche
Workrite Ergonomics	http://www.workriteergo.com/ergonomics/articles.asp
Gigablast	http://www.gigablast.com/

ASK	http://de.ask.com/#subject:ask|pg:1
Directory of open access journals	http://www.doaj.org/
Karlsruhe Virtual Catalogue	http://www.ubka.uni-karlsruhe.de/kvk.html
Google Scholar	http://scholar.google.de/

Table 10 lists the search terms, which were used in different combinations and variations.

Table 10: Keywords used for the web search

Usability of mobile devices
Mobile/portable devices
Cognitive ergonomics
Portable IT/Information technology
Communication device
Laptop, handheld, mobile phone, PDA,
Occupational health and safety
Safety at work
Small display
Ergonomic risks of handheld devices
Risk of handheld devices
Usability mobile devices
Usability mobile communication solutions
Ergonomic risks handling mobile IT devices
Mobile devices problems in application
Handling
Risk, health risk
Multitasking
Deviation, defection, avocation, distraction, diversion

This procedure led to a collection of 61 scientific and non-scientific articles. Overall, there are as yet few reports on specific risk factors such as noise, use in cold environments, repetitive movements or low levels of ambient light with a special focus on PSs. Consequently, there is still a great deal of research to be done on this issue. However, research findings for fixed or stationary workplaces can, for the most part, be applied to PSs as well. This chapter therefore brings together:
1) Current research findings with a specific focus on PSs;
2) Research findings based on stationary and instant workplaces but which allow predictions to be made regarding the impact of working with PSs.

As the research findings are broadly applicable to the whole field of mobile work, a rather general approach is taken here. The literature is analysed with respect to the risk factors addressed. Then, a description of the risk factors and an assessment in the context of mobile work is attempted. Wherever applicable, the review also highlights the influence of age and gender on these risks, as well as the changes likely to take place as the technology and its use are developed and improved.

2.1 The effects of biomechanical workload

While operating a PS on the move, biomechanical load may arise from manual handling, repetitive movements or static and/or poor posture.

As indicated in an earlier chapter "Overview of the technology and its use", there are various portable systems (PSs) with different specifications in use. The use of the PS in the field depends mainly on the task to be performed with it. These tasks are often determined by professions or professional categories. This must be taken into account when attempting to identify and assess possible health problems due to the ergonomic risk factors of PS use.

Firstly, the use of laptops by white-collar workers is considered. Where they are utilised by workers performing office, administrative, sales or managerial tasks, the ergonomic risk factors seem to be similar to those attached to stationary VDU workstations. While in most cases the tasks are the same at stationary and instant workplaces, the ergonomic risk factors are likely to be aggravated in instant workplaces due to the constant use of laptops in a sometimes unsuitable environment and without time limits controlled by workflow procedures. The postures adopted are presumed to be worse than at a stationary workplace because a desk top of adequate height may be missing, no suitable seating may be available and, due to the physical design of a laptop, the keyboard cannot be freely positioned. Thus, the impact of repetitive movements may be higher and may further increase due to overtime work and the absence of breaks. Vickery (2000), in fact, found that the use of laptops leads to an increasing number of complaints of musculoskeletal problems. The musculoskeletal problems of 508 respondents from a random sample of 626 staff, 40 % of whom use laptops during their office-based, manufacturing or home-based occupations, were surveyed (Mc Atamney, 2001): "83% of the sales force, who used laptops, reported one or more musculoskeletal disorders and 14 % of those who used a laptop for more than one hour a day reported significantly higher levels of elbow pain ($p<0.05$). Additionally, 72 % of employees who used the laptop for four hours or more a day reported a significant increase in back pain ($p<0.05$) compared to those who used it less often. There was a higher level of lower back pain in the laptop users (59 %) compared to the rest of the sample (49 %), which included industrial staff who undertook manual handling operations."

In order to tackle problems like these, Mc Atamney (2001) and other authors (i.e. Dreier & Feder (2001), van Harten (2007), Heegner (2007)) tried, as far as possible, to apply the ergonomic recommendations of Council Directive 90/270/EEC of 29 May 1990 to the use of laptops, and include them in the minimum health and safety requirements for work with display screen equipment (fifth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC) and the German Health and Safety Regulations for Working with VDU Equipment ("Bildschirmarbeitsverordnung"). To enable employees to follow ergonomic rules when arranging their PS and all the peripheral equipment as closely as possible at any place, it is proposed to teach ergonomics in specific situations; e.g. laptop use in the classroom, whilst travelling etc. Decisions on additional equipment to help overcome difficult conditions should be made on a case by case basis. This means, for example, that if the space available on a work surface is very limited, it may be advisable to use a trackball instead of a mouse (Keller Chandra et al. (2008)). However, despite the input devices built into laptops, the use of a mouse as a pointing and input device whenever possible is recommended on the basis of both best performance test results and subjective usability ratings (Baldus & Patterson (2008), Sutter et al. (2008)).

Aside from musculoskeletal load caused by poor posture, another health risk attached to laptops has been identified. The term "laptop" suggests that notebook computers are designed to be positioned on the lap. In his study, Shenykin (2004) proves that such a mode of operation causes a significant rise in scrotal temperature as a result of heat exposure and posture-related effects, i.e. closing the thighs to comfortably balance the notebook computer on the lap. Since scrotal hyperthermia has been identified as a risk factor for male infertility, the use of notebook computers positioned on the lap should be avoided. Further studies of such thermal effects on male reproductive health are warranted because long-term exposure to laptop-related repetitive transient scrotal hyperthermia is a modern lifestyle feature. Therefore, the possible negative impact upon spermatogenesis, specifically in teenage boys and young men, ought to be assessed.

Secondly, it is necessary to examine the attitude of workers who perform manufacturing, maintenance or technical support tasks with laptops and other PSs. Even though ICT devices, in particular personal computers, have become part of nearly everybody's everyday life, some people remain relatively unfamiliar with these technologies. Workers performing office or administrative tasks are commonly used to, and trained in, computer work as part of their jobs, but workers performing manufacturing or technical support tasks often have to learn computer skills before they can benefit from PSs in their working environment. They may feel the mental workload and time pressure growing while they try to apply newly gained knowledge to the performance of habitual tasks. At the same time, computer novices will no doubt find it more complicated to lay out an "ergonomic instant VDU workstation" on their own. These circumstances may explain certain reservations towards laptop and other PSs use on the part of this group of workers (Bowden et al. (2003)). It is well known that all these factors may act together to increase the biomechanical load on the musculoskeletal system.

Current research focuses not only on technical problems, like small screen size, short battery life or limited memory (Pettit & Kukulska-Hulme, 2007), or hardware limitations, like slow and unreliable network connections, limited data transfer or slower CPUs (Johansson, 2006), but also simultaneously addresses ergonomic issues.

According to Jøssund (2006), typing on a handheld device is extremely difficult unless a keyboard is attached. She also states that handwriting recognition software requires users to be trained in specific writing styles, such as block letters, etc. Mekelburg (2005) focuses on adaptable keyboards for fast data entry on mobile devices. He compares current typing systems like the phone pad system, mini- QWERTY and FASTAP, touchscreen with stylus and the thin or half QWERTY. The author makes several demands on the input devices. The keyboard should:

- allow fingers to be placed in a natural position;
- provide buttons which are easy and comfortable to press;
- allow for a large range of natural movements;
- improve mobile text entry;
- be easy to store;
- be usable with either hand;
- be usable on its own, i.e. without additional devices;
- be able to be interfaced to any device;
- be robust/rugged enough to endure rough handling;
- be weather resistant.

Schülke (2003) surveys the use of PSs in an industrial context. He also requires PSs to allow fingers to be placed in a natural position, to provide emergency stop switches and to possess switches which are easy and comfortable to press and to be usable with either hand. Skourup (2001), too, shows the relevance of well designed mobile workplaces in automation and industrial applications. She notices that the choice and design of mobile workplaces is not always adapted to the needs of the mobile worker. Although the interface and software are to assist mobile workers in fulfilling their tasks, they are rarely involved in the process of selecting and designing the technical equipment. Therefore, Skourup recommends that PSs in industrial settings should:

- allow hands-free operation;
- fulfil the requirements of data and information access;
- provide specific solutions for communication;
- be adequate for the prevailing environmental conditions.

Bowden et al. (2003) show the application of PSs on construction sites. As the construction site is a tough environment with sunlight, rain, mud and heavy handling, PSs have to meet high demands. The authors make clear that the user's preference or the suitability of a certain PS depends on the specific tasks to be performed. Participants preferred PDAs (Personal Digital Assistants) for inspection test sheets. Robust PDAs and PDA phones were preferred for statement and diary tasks and PDA phones for drawing tasks. Remarkably, 88% of the participants confirmed that they were happy to use one of these devices for their work, which shows the benefits of PSs in the working environment.

In conclusion, researchers commonly consider the ability to hold a device easily in one hand as an advantage. This is irrespective of the specific application or conditions of use (see e. g. Wilson & Landoni, 2003; Mekelburg, 2005; Schülke, 2003 or Skourup, 2001). Since both hands are required for keyboard input and placement, Zhu et al. (2002) consider pen-based interfaces on PSs as more suitable for fieldwork environments as the user typically stands whilst operating other devices.

According to Schedlbauer and Heines (2007), there have been few studies on the effects on interaction with mobile computing devices and task performance when the user is moving, e.g. walking slowly. They identify target selection, swiping, scrolling and drag/drop as typical actions when dealing with these PSs. They call for statistical data to guide designers of desktop-oriented devices in a mobile work context. The aspects of task interference are examined later in this chapter in the section on effects of cognitive load and multiple task situations.

When considering static and poor posture resulting from using a PS in an unsuitable environment or from working in an improperly installed instant workplace, research findings always recommend the reduction of weight and the provision of special installation and transportation aids (s. von Harten, 2007). Mc Atamney (2001) clearly states that the human body is not designed to be positioned in front of a monitor for most of the working day. In her case study of a 24-year-old female mobile worker she discovered that the participant's neck, shoulder, back and hand postures were contributing to overloading the musculoskeletal system. After three months she noticed pain in the right palm and hand, and after five months the symptoms had been diagnosed as carpal tunnel syndrome.

Since the mobile phone is a crucial device for most mobile workers, the consequences of its use, i.e. resulting ergonomic risk factors, will be mentioned here as well. Chany et al. (2007)

investigated the effect of mobile phone design on upper extremity discomfort and muscle fatigue. Their findings show that participants with more abduction strength, wider palms, and broader thumbs had increased mean discomfort in the neck and shoulder when dealing with small clamshell phones. Small clamshell phones generally increased hand discomfort and thenar muscle fatigue during use, while the grip style contributed to the development of discomfort and muscle fatigue by changing muscle length.

Baber (2001) focuses on weight and locations for displays when studying portable computers with respect to human factors. He investigated PSs applied in vehicle inspection, aircraft or warehouse work in an exemplary manner. Basically, the human body can carry loads on the head, the shoulders or the back. Apparently, on-body equipment can have an effect on posture and mobility, and there are potential physical effects of carrying such loads. Baber suggests that the total equipment weight should not exceed 30 % of the total body weight of the user and proposes the forearm as an alternative location for the display of a PS. The forearm is considered as an appropriate place to mount devices, and the torso a poor one to position pointing devices. Although there is a lack of statistical data and experimental studies, researchers and consultancies such as “ergonomicofficeTM” recommend short breaks because these are deemed beneficial for eyes, neck, shoulders, arms, hands and fingers.

2.2 Effects of the visual interface design

Several authors (e.g. Kiper (2007), Dreier & Feder (2001), von Harten (2007) and Heegner (2007)) apply the German Health and Safety Regulations for Working with VDU Equipment (”Bildschirmarbeitsverordnung”) to mobile working contexts, especially for the use of notebooks. In conclusion, and for this working context, their recommendations are similar: high resolution, sufficient font and icon sizes and flicker-free displays. Experimental studies, e.g. by Alexander et al. (2007), highlight the necessity of adequate icon and font size for data entry tasks using PSs.

According to Laur (2002), contrast is the crucial criterion for the legibility of a display. And because anisotropic liquid or liquid crystals in TFT displays are temperature sensitive, he pays special attention to the mobile working context. The ideal temperature for the functioning of the anisotropic liquid is 25°C. Deviation may lead to malfunction. He therefore recommends special design features in PS displays, such as back lighting. Wilson & Landoni (2003) agree with Laur and propose display technology with high resolution, high contrast, minimal glare and backlighting for mobile applications. Wu et al. (2007) compare a PDA (3.5 inch diagonal TFT-LCD screen), an e-book reader (6.5 inch diagonal SSCT-LCD screen) and a Notebook computer (14.1 inch diagonal TFT-LCD screen) for prolonged reading tasks. In the first instance, users still prefer printed books to e-books. Thus, the authors assert that the latter need to be well designed if they are to become widely accepted and used effectively. Their results show that the type of display has a statistically significant effect on reading performance, visual fatigue and user satisfaction. The PDA led to obvious visual fatigue after the subjects had been reading for 100 minutes. Only when portability was considered did the PDA have a significantly better rating than other PSs. All in all, the small size of screen was identified as a key limitation to applying a PDA to prolonged reading tasks.

Finally, display size is also interrelated with the user’s ability to process information. According to Zhu et al. (2002), screen size limitation causes input limitation to the user and, conversely, output limitation of the PSs.

2.3 Effects of excessive noise and vibration levels

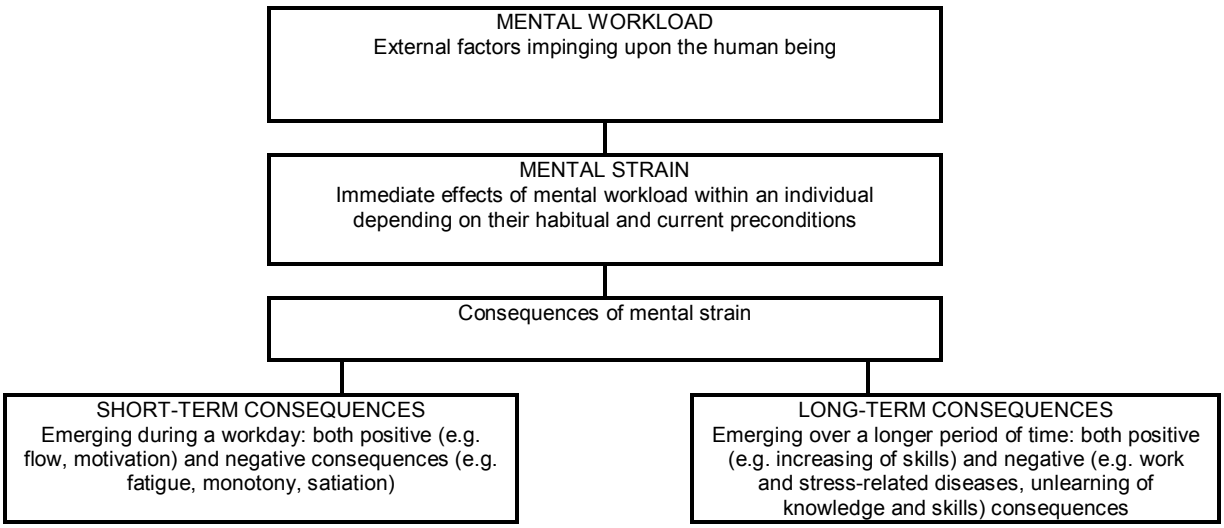
There is hardly any research available on excessive noise levels or background noise in working contexts with a special focus on PSs. Here, general statutory regulations or standards could be consulted and applied.

However, Sundström & Khan (2008) noted the effect of constant lateral vibration on train passengers' ability to read and write. Their laboratory study involving 48 subjects reveals a significant relationship between the tasks, vibration level and postural conditions. The subjects reported greater difficulty while reading and writing on the table than while leaning back. This may be of relevance for mobile workers in industrial contexts as well, because critical vibration levels may be present here, due to machinery in the working environment.

2.4 Effects of cognitive load and multiple task situations

Richter et al. (2006 in J. H. Andriessen & M. Vartianen) provide an overview of the study of modern mental workload and describe research into mental strain in the context of mobile virtual work (for definitions see chapter II). With reference to "ISO 10075:1991 Ergonomic principles related to mental work-load – General terms and definitions", mental workload at work and its consequences, such as mental fatigue or reduced vigilance, are examined.

Figure 18: Mental workload, mental strain, and consequences of mental strain according to ISO EN 10 075



Source: Paridon & Hupke, 2008.

When dealing with mental workload, the authors (chapter III on "Psychosocial Resources and Risk Factors of the Increasing Use of Portable Computing and Communication Devices") consider, amongst other things, an intensive interaction with ICT tools compared to non-virtual working situations. For this they assume higher levels of cognitive demands on mobile workers.

Basically, the use of PSs during work in a mobile context can be considered from the perspective of the so-called dual-task paradigm, in which users have to perform two tasks simultaneously. Evidently, human processing resources are limited and shared and can be

subdivided into several classes. Different tasks may compete for the same information processing resources in the brain. This commonly leads to task interference and performance loss in either one of the tasks.

There is a variety of empirical research into dual-task trade-offs while driving. This gives an initial insight into working conditions with PSs and provides transferable results concerning cognitive distraction, inattention, increased reaction times and similar effects. The majority of mobile phone-related car accidents in Japan and the United States occur during dialling, receiving calls or during conversation (Lamble et al., 1999).

According to Lamble et al. (1999) and other general research findings, manipulating, looking at and talking into a mobile phone can all increase the risk of a car crash. Findings by Brumby et al. (2007) support this conclusion. Here, engaging in a secondary task, such as dialling on a mobile phone while driving a car, has also been found to have a negative effect on driver performance.

Chittaro & De Marco (2004) distinguish between different types of distraction. The general withdrawal of attention means taking the eyes off the road or the critical target. This is due to eyelid closure or glances away from the critical target. Selective withdrawal of attention means "mind-off-the-road" due to daydreaming, for example. Finally, the biomechanical interference indicates the reduction of the user's ability to execute manoeuvres due to body posture shifts or similar, e.g. when reaching for a mobile telephone or leaning over to see or manipulate a device while driving. The latter type of distraction may be eliminated with the help of technical solutions such as hands-free PSs, i.e. hands-free mobile phones in driving situations. This cannot, however, reduce possible cognitive distractions which occur while handling the PSs.

The scheduling of multiple tasks causes interference and often one task is temporarily neglected in favour of another. For example, attention is taken from the primary task (driving) while operating an in-vehicle navigation system, a PDA, or dialling on a mobile phone. A potential cause is that a particular task, for instance the use of a particular PS is too difficult and the mental workload increases to such an extent that the situation becomes unsafe, and accidents can occur. Chen et al. (2008) examined the hypothetical benefits of in-built vehicle input/output and display systems for so-called "nomadic" devices. Their study shows that the interface developed reduces mental workload compared to using the "nomadic" devices without such interface and results in less neglect of the driving task.

Alexander et al. (2007) also state that, when dealing with PSs and data entry in a mobile context the task of moving is the primary task, which has to be performed in a safe manner. This influences performance in the secondary task. People may potentially vary the extent to which two tasks are interleaved. There is a strategic variability in multitasking behaviour, because attention may be turned to a certain task less often while performing another task. However, an increase in the total time to complete the task may be expected because of frequent task interleaving.

Schedlbauer & Heines (2007) investigated interactions with PSs while walking. They demonstrated interaction effects of walking and task performance when using a PS corresponding to the effects of dual or multiple tasking described above. They cite research findings that show that the difficulty of walking through an obstacle course influenced the performance of the user with the PS. The main result was that participants noticeably slowed down their walking speed when selecting targets on the PS display. Again, the results make

evident that there is a definite connection between selection performance and walking. Several studies show the multitasking characteristics of specific working contexts. Wittenberg (2005) illustrates the cognitive demands on mobile workers in automation and industrial contexts. Here, maintenance and monitoring tasks require the simultaneous handling of different processing and production facilities with PSs. Oulasvirta & Sumari (2007) also examine managing multiple PSs in mobile working contexts. According to them the most salient problems are:

- The physical effort required by various management tasks;
- Anticipating what data or function will be needed;
- Aligning these efforts with work, mobility, and social situations.

Participants in their study had to handle a smart phone, a laptop, a mobile phone and various necessary accessories such as docking stations, chargers, headsets, cables, etc. The authors show that having to synchronise different PSs requires careful cognitive effort. Therefore users often prefer to use only one device. These results suggest that there may be value in designing mobile devices that facilitate multitasking behaviour for mobile workers. Future PSs may be sensitive devices such as so-called workload managers or peripheral displays (Bruno, 2005), which facilitate synchronisation and the use of different working areas.

Apart from the effects of multiple tasking, the design of PSs' menus and similar applications may contribute to a user's cognitive load as well. For example, Beier (2004) recommends that basic applications be accessible with very few clicks. Zhu et al. (2002) refer to this type of requirement as well. They claim that proper categorisation, fewer key-press actions, and better visualisation can ease the use of wireless computing. Ziefle et al. (2006) show that a user's mental representation of how a technical device might be structured clearly affects performance outcomes and may lead to disorientation within the menu. As seen in the section on the effects of visual interface design, screen size may affect cognitive load as well. In this context, Jøssund (2006) states that small screens should have shallow navigational hierarchies in order to offer overview and transparent navigation.

2.5 Effects of Ageing

While examining the design of mobile phones for older users, Pattison & Stedmon (2006) demonstrated that there are several ergonomic implications for the elderly. They describe the effects of ageing on vision, hearing and motor function, which influence the interaction with PSs and lead to special requirements for this user group. According to the authors, older people require more light than younger ones to see the same level of detail. Most displays are too small for the elderly. They also have difficulties with glare. As information processing and long-term memory decline with age, a disproportionate increase in cognitive load caused by multi-functional PSs could be expected in older users.

As a result, older users encounter a number of problems when interacting with PSs. Aschersleben & Müsseler (2007) point out that task interference in dual-task situations is especially critical for the elderly. Finally, Chittaro & De Marco (2004) show that this is particularly crucial in driving tasks. Their findings prove that older drivers take longer to respond to warnings on head-up-displays, to read maps in a simulator, to read maps on the road and generally make more mistakes. In general, driving in "normal" conditions already imposes a larger cognitive load on older drivers than on younger ones.

2.6 Discussion and Conclusions

The preceding sections have given an overview of literature dealing with ergonomic risk factors arising from the use of PSs. Ergonomic risk factors have been described in detail, and recommendations or – sometimes tentative – guidelines derived, to be followed if adverse health effects or the risk of accidents are to be avoided.

In fact, the number of relevant articles was relatively small and only few studies were specifically concerned with biomechanical issues with a particular focus on PSs. This is also true for environmental risk factors such as noise, vibration or low levels of ambient light. And finally, no remarks on gender issues could be found in the articles selected. In most cases, the studies deal with the examination of a certain PS device in use for mobile work. For this reason and due to the scarce statistical data on the duration and extent of PS use in an occupational environment (chapter II), research findings remain scattered. Therefore, further research needs to be conducted to piece the puzzle together and to obtain a full picture.

But how could the difficulties of avoiding any unpredictable ergonomic pitfalls in all the possible scenarios be overcome? How could general measures be taken to solve the problem that PS devices often have to be tailored for specific tasks and the user population in terms of, for example, ICT skills, age and gender?

As mentioned in the conclusions to chapter II and the section "Effects of biomechanical workload", a distinction between different professional categories or groups of workers seems advisable. In addition to the different work environments of mobile eWorkers, these categories allow for a differentiation in the intensity of PS use and of ICT skills in most cases. Since the duration and intensity of PS use are crucial factors for biomechanical workload, the workflow must be analysed (chapter III.1.1 on Psychosocial Resources and Risk Factors). Of course, while differences in the various professional categories affect the total amount of biomechanical and cognitive workload, they may also be helpful in determining the resources that help users to cope with that workload.

Given the above, account should be taken of the likely development of technologies in the future. As mentioned in chapter II, this development will probably lead to PSs designed for communication tasks. Because of their smaller size and weight in comparison to those designed for computing tasks, they are likely to reduce biomechanical load and be more appropriate for supporting mobile work. It is also becoming apparent that there is a need for user-centred design of mobile devices which limit the cognitive load for mobile workers. Future PSs should, for example, facilitate multitasking behaviour. If computing tasks could then be run on servers that are connected to those PSs via Internet or other networks, PSs designed for computing tasks would no longer be needed. Therefore, the focus of research activities in the field of work-related adverse health effects and accidents due to occupational use of PSs on the move should be put on design criteria for PSs for communication purposes.

IV Implications for the Management of OSH

In this section implications for the management of OSH for mobile IT-supported work are investigated. The information collected in chapters II and III is analysed in terms of the challenges that these and future developments pose to enterprises' management of OSH.

The main problems and difficulties in applying "traditional" approaches to OSH management to mobile IT-supported work are described, and possible solutions are illustrated. Additionally, some consideration is given to whether the use of mobile communication and computing devices leads to mobile workers being left out of collective agreements.

1. Difficulties in applying "traditional" approaches to OSH management

The Framework Directive on the introduction of measures to improve the safety and health of workers at work (89/391/EEC) provides the basis for all an employer's OSH activities. The Directive is applicable to all sectors of activity, both public and private (Art. 2,1) with the exception of certain specific public service activities, such as the armed forces and the police, or to certain specific activities in the civil protection services (Art. 2,2). Thus, the Framework Directive is applicable to all kinds of mobile IT-supported work covered by Art. 2,1.

In addition to general provisions on OSH, the Directive gives the employer certain specific obligations regarding the management of safety and health at work as a process, e.g.:

- Prevention of **occupational risks** and provision of **information and training**, as well as provision of the necessary organization and means (Art. 6,1);
- Responding to **changing circumstances** and aiming to **improve existing situations** (Art. 6,1);
- The duty to **ensure the safety and health** of workers in every aspect related to their work (Art. 5,1);
- Observing the following general principles of prevention: (a) **avoiding risks**; (b) **evaluating the risks** which cannot be avoided: (c) **combating the risks at source** (Art. 6,2).

On the one hand, these and other obligations are general enough to be applicable to the management of OSH for all kinds of work with respect to Art. 2,1. On the other hand, they are too general to provide specific measures and directives for the management of OSH for mobile IT-supported work. To apply the general OSH provisions of the Directive to specific work settings, the following key questions need to be answered:

i. Which are the domains of mobile IT-supported work that bear the highest risks for the employee's health at work?
ii. Which of these domains could be subject to the employer's OSH management, and how?

The answer to question (i) can be derived from the results of chapters II and III. The following domains bear the main risks:

Table 11: High-risk domains in mobile IT-supported work

Domain	Risks	Task	Inv.
Technology	Miniaturisation of devices	1	
	New technologies (e.g. e-paper, wearable computers)	1	
	Poor visual interfaces	2a	*
	Repetitive movements	2a	*
Work environment	Excessive noise levels	2a	
	Static and poor posture	2a	
	Cognitive overload	2a	
	Multitude of work-settings	1	
	Soaring mobility and micro-mobility	1	
Work organisation	Increasing work-load	2b	*
	Longer working hours	2b	*
	Communication barriers	2b	*
	Reduced access to information	2b	*
	Permanent reachability	2b	*
	Difficulties in leadership	2b	*
Working individual	Dual use of devices (work, private)	1	*
	Increased autonomy	2b	*
	Necessity for self-management	2b	*
	Lack of social support	2b	*

In order to answer question (ii), it is important to note that some of these domains contain variable factors. However, only those factors which remain constant in different aspects of work, so called invariants, can serve as the basis for OSH measures. For example, OSH measures aimed at designing, and probably regulating, the work place are not feasible within the context of mobile IT-supported work, since the workplace is variable (Kohn, 2008).

Difficulties in applying traditional approaches to OSH management may arise for three reasons:

Firstly, only those factors in table 11 that are considered invariant (marked with an asterisk *) may be subject to OSH management. A variable, i.e. unpredictably changing, factor may not be managed by static directives. For factors which are variable under mobile IT-supported work and cannot be managed company-wide, e.g. the work environment, it is only possible to give guidelines and training to the employees on appropriate individual behaviour in certain situations.

Secondly, variable factors may not be subject to OSH management because of their lack of controllability. In general, the intended effect of each measure of any management discipline is guaranteed only to the extent to which it can be controlled and monitored. In the case of mobile IT-supported work, it would not be possible to effectively measure and monitor any OSH measure that addressed a variable factor, e.g. place and time of work, or intrusion of

work into private life. Since many of the traditional approaches to OSH management do address the factors and domains that are variable under mobile IT-supported work, problems with these approaches are inevitable.

Thirdly, as table 11 also indicates, most of the factors which are invariant and thus susceptible to OSH management are within the domains of organisation and processes (see also Kohn, 2006).

A glance at the OSH Framework Directive 89/391/EEC, which lists many issues from these domains (see table 12 for examples) supports this observation. Difficulties in traditional OSH management may arise from the traditional separation of sub-organisations within a company: The OSH department usually does not deal with process management. The process management department is primarily concerned with process efficiency and not good working conditions, and the human resources department, which is responsible for education and training, has little knowledge of every-day work processes and their specific impact on employees' health.

Table 12: Domains of some OSH Framework Directive issues

Issue	Article	Domain
Provision of information and training	6.1	Process
Design of work places	6.2 d)	Organisation
Choice of work equipment	6.2 d)	Technology
Choice of working and production methods	6.2 d)	Processes
alleviating monotonous work	6.2 d)	Processes
alleviating work at a predetermined work-rate	6.2 d)	Processes
adapting to technical progress	6.2 e)	Technology
appropriate instructions	6.2 i)	Processes

2. Exclusion from collective agreements due to mobility

Collective agreements between employers and their employees are an additional tool for managing invariant concepts of work within an organisation for domains in which existing directives and regulations:

- do not exist or are not applicable,
- need to be rendered more precisely.

For mobile IT-supported work, the most common issues subject to OSH management by collective agreement are:

- the amount of working time,
- access to the organisation's flow of information,
- inclusion in the organisational work flow.

The advantages of collective agreements as a tool for OSH management are their individuality, flexibility, and their independence of existing directives. With collective

agreements, aspects of mobile IT-supported work which are not covered by any directives can be made accessible to OSH management.

The disadvantage of collective agreements is the potential exclusion of mobile employees due to the insufficient controllability of such agreements in their case and the lack of clearly defined responsibilities. A collective agreement on working time that works well within the organisation is difficult to monitor for mobile workers, since there is no mechanism for monitoring the specified working time for employees working outside the organisation. Especially if the leadership model for these employees is based on management by objectives, employees often tend to work overtime if the objectives have not been appropriately chosen. In this case, the mobile employees are effectively excluded from this collective agreement.

Closely related to the unenforceability of collective agreements is the lack of clearly defined responsibilities. If a collective agreement on, for instance, working time specifies that the employer is responsible for compliance, the problem of monitoring would apply. If, on the other hand, the employee is considered responsible, the obligation to provide appropriate measures for OSH would be transferred from the employer to the employee.

Neither problem can be solved by implementing additional regulations, directives or agreements. Instead, the solution may lie with an appropriate corporate culture with a special focus on prevention.

3. Consequences and recommendations for practical OSH management

Due to its complexity, mobile IT-supported work needs holistic, and probably new, methods of practical OSH management by the employer. Though far from comprehensive, the following consequences and resulting recommendations may be viewed as a first approach.

- A company's OSH management cannot manage all aspects of mobile IT-supported work in detail, since there are factors which are highly variable, and thus simply not manageable. As a consequence, the employer should:
    - identify all relevant **invariant** aspects of mobile IT-work (e.g. devices, work-load, communication structures) and establish appropriate measures based on the relevant OSH Directives, scientific research results, and examples of good practice;
    - identify all relevant **variable** aspects of mobile IT-work (e.g. changing work-settings, individual thresholds for cognitive and information overload, individual preferences on work-life balance) and give guidelines and/or training to the employer on appropriate individual behaviour based on scientific research results and examples of good practice.
- Due to the complexity and multidimensionality of mobile IT-supported work an effective OSH management within a company must deal with domains that are beyond the traditional framework of OSH. Many issues are located within the domains of other "managements" within the company, e.g. process management, human resources management, health care management, quality management, or financial management. Traditionally, each of these domains is represented by a specialised department, with well-defined internal organisational boundaries. Thus, the employer should:

- dissolve internal boundaries between those sub-organisations that in any way contribute to the design of work and work processes;

- encourage cooperation between these units in order to holistically establish healthy working conditions for the employees.

- Many OSH aspects of mobile IT-supported work may not be manageable or controllable but have to be incorporated into a living culture, e.g. trust in, and appreciation of, the employees. The employer should therefore:

  - strive to establish a corporate OSH culture;

  - establish human needs as one of its core values.

- OSH management for mobile IT-supported work has to be done holistically. However, due to the complexity of this form of work OSH management cannot be established as a whole in a single step. Instead,

  - the implementation of OSH management for mobile IT-supported work should be carried out in a process of several successive steps:
    - prioritisation of domains and factors based on their impact on safety and health,
    - selection of the most crucial factors,
    - (re)design of the corresponding measures for OSH.

When these measures have been implemented, the process continues into its next cycle with a repetition of the prioritisation and selection steps.

- In mobile IT-supported work the employee has influence on more aspects of work than in "traditional" forms of work. Employers should take this into account in their OSH management by:

  - building awareness on the part of the employees of OSH aspects in their own concerns;

  - enabling the employees to make responsible use of their potential, e.g. by giving them appropriate and individual training.

4. Conclusions

Mobile IT-supported work is considered hard to design and regulate for occupational safety and healthy aspects. This is due to the fact that many aspects of work which are invariant in traditional work settings become variable within mobile IT-supported work. OSH principles and measures which are based on such factors thus are no longer applicable within this new form of work. In this way, mobile IT-supported work confronts corporate OSH management with new challenges. Many of the factors relevant for OSH in mobile IT-supported work are located within the domains **organisation** and **processes**. OSH management, therefore, must depart from its traditional approach of observing statutory restrictions and regulations for safety at work. Instead it should facilitate a holistic approach in cooperation with other organisational management disciplines. This seems to be the key factor in successfully enabling occupational safety and health in mobile IT-supported work and thus protecting the individual's health.

V Implications for regulation and enforcement

Summary

The questions to be answered in this part of the report concern the main challenges for legislation and enforcement arising from the increasing use of portable computing and communication devices and systems.

The existing European legislation was analysed against the background of the new requirements arising in practice.

Several options for adapting the legislation and alternative solutions for coping with new and future developments in this field are presented and discussed.

The main questions to be answered are:
- What are the new challenges presented by the growth in work with portable computing and communication devices?
- To what extent is current OSH legislation able to ensure proper control of the risks?
- What are the options for legislation and enforcement to cope with the demands posed by work with portable devices?

1. Challenges and possible approaches for legislation and enforcement

On the basis of the results from chapter II "Overview of the technology and its use", chapter III "Assessment of the OSH risks" and chapter IV "Implications for the Management of OSH", the main challenges are:
- Blurred boundaries between private and occupational use in terms of systems/devices and time;
- Employer's limited control of field work;
- Relative autonomy of field workers;
- Adaptation of prevention obligations to the accelerated pace of technical progress.

General solutions for regulation to be considered are:
- Changing/extending of existing obligations; concerns of the employer, concerns of the employee.
- Binding obligations and/or recommendations.
- Are innovative approaches possible?

General approaches the authorities might follow are:
- Extending inspection to include work that involves the use of portable devices.
- Focussing on monitoring OSH management.
- More advice for employers and employees.

This short overview of the critical questions serves as a starting point for the analyses and the development of options presented in the following chapters.

The European Framework Directive on safety and health at work and its **relevant daughter directives: their application to work with portable computing and communication devices.**

Is the technology of portable ICT devices covered?
Are the risks adequately incorporated?
Are the requirements for OSH management considered?

1.1 OSH Framework Directive 89/391/EEC

The OSH Framework Directive "contains general principles concerning the prevention of occupational risks, the protection of safety and health, the elimination of risk and accident factors, the informing, consultation, balanced participation in accordance with national laws and/or practices and training of workers and their representatives, as well as general guidelines for the implementation of the said principles." (Articles 1, 2)

This means that the OSH Framework Directive formulates the basic requirements for work with portable ICT devices in every respect, as the following citations from the Directive will demonstrate. Statements of particular relevance to work with portable ICT devices are emphasized in bold by the author:

Art. 5, 1. ***The employer shall have a duty to ensure the safety and health of workers in every aspect related to the work.***

Art. 6, 1. ... the employer shall take the measures necessary for the safety and health protection of workers, including prevention of occupational risks and provision of information and training, as well as provision of the necessary organization and means.
The employer shall be alert to the need to adjust these measures to take account of changing circumstances *and aim to improve existing situations.*

Art. 6, 2. The employer shall implement the measures ... on the basis of the following general principles of prevention:
(a) avoiding risks;
(b) ***evaluating the risks which cannot be avoided****;*
(c) combating the risks at source;
(d) ***adapting the work to the individual****, especially as regards the design of work places,* ***the choice of work equipment*** *and* ***the choice of working*** *and production* ***methods****, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health.*
(e) ***adapting to technical progress****;*
(f) replacing the dangerous by the non-dangerous or the less dangerous;
(g) ***developing a coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment****;*
(h) giving collective protective measures priority over individual protective measures;
(i) ***giving appropriate instructions to the workers****.*

Art. 6, 3. ..., ***the employer shall, taking into account the nature of the activities of the enterprise*** *and/or establishment:*

(a) ***evaluate the risks to the safety and health of workers****, inter alia in the choice of work equipment, ... and the fitting-out of work places.*

Application of the above requirements and obligations to the responsibilities of employers concerning work with portable ICT devices

The employer shall have a duty to ensure the safety and health of workers in every aspect related to the work	The employer is fully responsible. No exception for any kind of work or workplace.
provision of the necessary organization and means	OSH management must also be organized in a manner which fulfils the implicit requirements for work with portable devices.
The employer shall be alert to the need to adjust these measures to take account of changing circumstances	OSH measures must also comply with the changing circumstances of mobile work
The employer shall implement the measures ... on the basis of the following general principles of prevention	
(b) evaluating the risks which cannot be avoided;	Mobile workers will inevitably encounter risks. The employer must evaluate these risks
(d) adapting the work to the individual ... the choice of work equipment ... the choice of working ... methods	Work must be adapted to the typically unique working conditions, including by means of appropriate portable ICT devices and their use
(e) adapting to technical progress;	The rapid pace of ongoing developments in portable ICT technology must be given timely consideration and anticipated before new problems and risks arise
(g) developing a coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment;	Work with portable devices, typically extramural and during business travel, requires companies to have a coherent overall prevention policy adapted to this kind of work.
(i) giving appropriate instructions to the workers	Work with portable devices requires special training and instruction of the workers in order for awareness of health and safety risks to be increased, for the risks to be managed, and also for the devices and tools to be used correctly and without stress
..., the employer shall, taking into account the nature of the activities of the enterprise ... *(a) evaluate the risks to the safety and health of workers*	The employer must have access to an evaluation which takes into account the nature of portable ICT devices and the activities in which they are used

It is clear that the OSH Framework Directive covers all risks and all forms of work, and that it addresses the full breadth of obligations upon the employer. The requirements are applicable to all specific aspects of work with portable devices. From this point of view, the OSH regulations are comprehensive.

1.2 Possibly relevant EU regulatory framework

Directive 90/270/EEC (work with display screen equipment) seems to rule itself out, since:
"This Directive shall not apply to: ... (d) 'portable' systems not in prolonged use at a workstation;" (emphasis added by the author)

On the other hand, the following daughter directives may appear at first glance to be applicable to the specific problems discussed with respect to work with portable ICT devices, owing to their intended purpose:

Directive 89/655/EEC (use of work equipment by workers at work)
The purpose of this Directive is that of defining minimum requirements for work with possibly dangerous work equipment such as machines, etc.

Directive 2003/10/EC (on risks arising from physical agents (noise))
"This Directive ... lays down minimum requirements for the protection of workers from risks to their health and safety arising or likely to arise from exposure to noise and in particular the risk to hearing." (emphasis added by the author). Risk to hearing posed by noise is not a typical problem of work with portable ICT devices.

Directive 90/269/EEC (manual handling of loads where there is a risk particularly of back injury to workers)

The purpose of this Directive is that of preventing back injuries to workers caused by the manual handling of loads. Heavy loads are meant in this context and could be taken into account only if a worker were to use a workstation computer as a portable ICT device.

Directive 2003/88/EC concerning certain aspects of the organisation of working time
"This Directive applies to:
(a) minimum periods of daily rest, weekly rest and annual leave, to breaks and maximum weekly working time; and (b) certain aspects of night work, shift work and patterns of work."
The Directive is in principle applicable to specific problems of work with portable devices arising for example from long working hours during journeys and from "mobile work", which is explicitly addressed in the Directive's articles 2, 7 and 20. This means that employers must pay special attention to the requirements of this Directive with respect to "adequate rest" for their mobile workers.

However, after consideration of the details of the above directives, they appear – with the exception of the general requirements for the organisation of working time – inapplicable to the specific problems of work with portable ICT devices.

1.3 Directive 90/270/EEC (work with display screen equipment)

This Directive is also known under the title "VDU Directive" (Visual Display Unit Directive). The VDU Directive was developed in the 1980s, when work with visual display units, for instance in offices, rose sharply as a "new form of work". It addressed the new challenges from a technical, organisational and medical point of view. The creation of a dedicated directive for this purpose appears to have been the correct decision.

The VDU Directive is restricted to stationary workplaces, for which its annex, in particular, is designed. Article 1, 3 states:
"This Directive shall not apply to:
(a) drivers' cabs or control cabs for vehicles or machinery;
(b) computer systems on board a means of transport;
(c) computer systems mainly intended for public use;
(d) 'portable' systems not in prolonged use at a workstation;
(e) calculators, cash registers and any equipment having a small data or measurement display required for direct use of the equipment;
(f) typewriters of traditional design, of the type known as 'typewriter with window'."

The conclusion is that work with portable devices is not covered by the VDU Directive.

However, if the details of this Directive are considered, one can see that although parts of the Directive are not legally applicable, they apply in practice to work with portable devices. For example:

"Article 3
Analysis of workstations
1. Employers shall be obliged to perform an analysis of workstations in order to evaluate the safety and health conditions to which they give rise for their workers, particularly as regards possible risks to eyesight, physical problems and problems of mental stress.
2. Employers shall take appropriate measures to remedy the risks found, on the basis of the evaluation referred to in paragraph 1, taking account of the additional and/or combined effects of the risks so found."

"Article 6
Information for, and training of, workers
1. Without prejudice to Article 10 of Directive 89/391/EEC, workers shall receive information on all aspects of safety and health relating to their workstation, in particular information on such measures applicable to workstations as are implemented under
Articles 3, 7 and 9.
In all cases, workers or their representatives shall be informed of any health and safety measure taken in compliance with this Directive.
2. Without prejudice to Article 12 of Directive 89/391/EEC, every worker shall also receive training in use of the workstation before commencing this type of work and whenever the organization of the workstation is substantially modified."

"Article 8
Worker consultation and participation
Consultation and participation of workers and/or their representatives shall take place in accordance with Article 11 of Directive 89/391/EEC on the matters covered by this Directive, including its Annex.

Article 9
Protection of workers' eyes and eyesight
1. Workers shall be entitled to an appropriate eye and eyesight test carried out by a person with the necessary capabilities:
- before commencing display screen work,
- at regular intervals thereafter, and
- if they experience visual difficulties which may be due to display screen work.

2. Workers shall be entitled to an ophthalmological examination if the results of the test referred to in paragraph 1 show that this is necessary.
3. If the results of the test referred to in paragraph 1 or of the examination referred to in paragraph 2 show that it is necessary and if normal corrective appliances cannot be used, workers must be provided with special corrective appliances appropriate for the work concerned.
4. Measures taken pursuant to this Article may in no circumstances involve workers in additional financial cost.
5. Protection of workers' eyes and eyesight may be provided as part of a national health system."

If we consider the annex of the VDU Directive as containing the "minimum requirements", it also applies in part to portable devices:

1. Equipment	Applicability of the requirements from the VDU Directive to work with portable devices
(a) General comment *The use as such of the equipment must not be a source of risk for workers.*	Applicable
(b) Display screen *The characters on the screen shall be well-defined and clearly formed, of adequate size and with adequate spacing between the characters and lines.*	Applicable
The image on the screen should be stable, with no flickering or other forms of instability.	Applicable
The brightness and/or the contrast between the characters and the background shall be easily adjustable by the operator, and also be easily adjustable to ambient conditions.	Applicable
The screen must swivel and tilt easily and freely to suit the needs of the operator.	Applicable
It shall be possible to use a separate base for the screen or an adjustable table.	Not applicable
The screen shall be free of reflective glare and reflections liable to cause discomfort to the user.	Applicable
(c) Keyboard *The keyboard shall be tiltable and separate from the screen so as to allow the worker to find a comfortable working position avoiding fatigue in the arms or hands.*	Partly applicable Notebooks with detachable keyboards are available
The space in front of the keyboard shall be sufficient to provide support for the hands and arms of the operator.	Partly applicable*
The keyboard shall have a matt surface to avoid reflective glare.	Applicable
The arrangement of the keyboard and the characteristics of the keys shall be such as to facilitate the use of the keyboard.	Applicable
The symbols on the keys shall be adequately contrasted and legible from the design working position.	Applicable

(d) Work desk or work surface *The work desk or work surface shall have a sufficiently large, low-reflectance surface and allow a flexible arrangement of the screen, keyboard, documents and related equipment.* *The document holder shall be stable and adjustable and shall be positioned so as to minimize the need for uncomfortable head and eye movements.* *There shall be adequate space for workers to find a comfortable position.*	Partly applicable*
(e) Work chair *The work chair shall be stable and allow the operator easy freedom of movement and a comfortable position.* *The seat shall be adjustable in height.* *The seat back shall be adjustable in both height and tilt.* *A footrest shall be made available to any one who wishes for one.*	Partly applicable*
2. Environment	
(a) Space requirements *The workstation shall be dimensioned and designed so as to provide sufficient space for the user to change position and vary movements.*	Partly applicable*
(b) Lighting *Room lighting and/or spot lighting (work lamps) shall ensure satisfactory lighting conditions and an appropriate contrast between the screen and the background environment, taking into account the type of work and the user's vision requirements.* *Possible disturbing glare and reflections on the screen or other equipment shall be prevented by coordinating workplace and workstation layout with the positioning and technical characteristics of the artificial light sources.*	Partly applicable * comparable working conditions may be sought
(c) Reflections and glare *Workstations shall be so designed that sources of light, such as windows and other openings, transparent or translucid walls, and brightly coloured fixtures or walls cause no direct glare and, as far as possible, no reflections on the screen.* *Windows shall be fitted with a suitable system of adjustable covering to attenuate the daylight that falls on the workstation.*	Partly applicable * comparable working conditions may be sought
(d) Noise *Noise emitted by equipment belonging to workstation(s) shall be taken into account when a workstation is being equipped, in particular so as not to distract attention or disturb speech.*	Partly applicable *
(e) Heat *Equipment belonging to workstation(s) shall not produce excess heat which could cause discomfort to workers.*	Partly applicable *
F)Radiation *All radiation with the exception of the visible part of the electromagnetic spectrum shall be reduced to negligible levels from the point of view of the protection of workers' safety and health.*	Partly applicable *
(g) Humidity *An adequate level of humidity shall be established and maintained.*	Partly applicable*

3. Operator/computer interface	
In designing, selecting, commissioning and modifying software, and in designing tasks using display screen equipment, the employer shall take into account the following principles: *(a) software must be suitable for the task;* *(b) software must be easy to use and, where appropriate, adaptable to the operator's level of knowledge or experience; no quantitative or qualitative checking facility may be used without the knowledge of the workers;* *c) systems must provide feedback to workers on their performance;* *(d) systems must display information in a format and at a pace which are adapted to operators;* *(e) the principles of software ergonomics must be applied, in particular to human data processing.*	Applicable

* Workplaces designed for work with portable systems are already or can be made available e.g. at railway stations and airports.

All the above quotations show implementations of the Framework Directive for work with visual display units. The employer can use also the VDU Directive as a **guideline** for state-of-the-art application of the Framework Directive for work with portable devices with display unit. This also includes the obligations for protection of workers' eyes and eyesight in Article 9 of the VDU Directive to comply with article 14 of the Framework Directive.
It should be mentioned that **in at least two member states, the legal implementation of the VDU Directive** does not exclude work with portable devices used externally to workplaces. The UK excludes only "portable systems not in prolonged use". This means that portable systems used for long periods of time are included even if they are used externally (not at workplace). Estonia excludes only "working short-term with laptop computers".

In order to answer the question of whether the VDU Directive, a new directive or some alternative solution would be the most appropriate approach to dealing with OSH problems arising from work with portable ICT devices it is important to find out which requirements necessary for work with portable ICT devices are missing from the relevant existing legislation.

The relevant legislation does not contain concrete requirements for certain specific aspects of work with portable devices, e.g.:

- ergonomic features of portable devices and systems;
- regulation of what are appropriate circumstances for extramural work with portable systems;
- requirements for the technical and personal support of employees who work with portable systems;
- requirements for training and qualification in order to raise workers' awareness and competence, to enable them to cope with health risks arising from work with portable systems;
- obligations for the protection of the eyes and eyesight of employees working with portable devices.

With the exception of the last point, i.e. examination of the eyes and eyesight, for example by an ophthalmological examination offered by the employer, all specific aspects mentioned above are difficult to regulate by concrete binding requirements. Instead, a need exists for

flexible solutions on the basis of a culture of prevention and personal competence on the part of the employer, and for technical and ergonomic standards for portable systems to be made available for occupational use by the suppliers. Good examples are the German GS label ("certified safety") and the private TCO standard governing CRT monitors for stationary workplaces.

2. Options for legislation and enforcement

Based on the analysis in chapter II, several options for the adaptation of regulation and enforcement to work with portable systems can be developed.
The options for legislative action are:

i. A new directive for work with portable systems.

In order to be an effective tool for setting OSH standards, this Directive ("Directive on the minimum safety and health requirements for work with portable computing and communication systems and devices") would have to cover all aspects of work with portable systems: the technical and ergonomic requirements for the portable systems, the requirements for the working environment, work behaviour and work organisation, training and qualification etc. Whether this Directive would be flexible enough to adjust to the growing pace of technological development, to cope with different aspects of mobile work with ICT systems, and to cover the diverse criteria of small enterprises and big companies remains questionable.

ii. Extending and updating the VDU Directive for work with portable systems.

As shown in chapter I, the requirements of the VDU Directive are also applicable to work with portable systems. Only the annex is specifically designed for VDU workstations. It appears feasible to establish a second annex to the VDU Directive for portable systems. This would, however, give rise to the same problems as mentioned above under point (i), were it to be necessary for the requirements for portable systems and work with them to be formulated with sufficient flexibility and detail. This solution would, however, have the attractive feature of being an adaptation of an existing directive, one which is widely known and accepted, to new developments in the area of work with VDU systems. Should this option be selected, the requirements in the new annex should be limited to certain principles, focussing upon requirements for the equipment and the devices, whereas working practices should be referenced to management practices in the form of best-practice examples.

This option appears to be preferred by some OSH experts, as the discussion at the workshop and communication from (for example) Finland (FIOH) show.

iii. Creation of new legal instruments or updating of an existing one (other than the VDU Directive).

As shown above, all aspects of work with portable ICT systems are covered by the principles formulated in the OSH Framework Directive. Nevertheless, most of the VDU Directive requirements may be used only as guidelines of good practice for working with VDUs in general and could not be applied as binding regulations for all workers and sectors involved.

In cases (ii) and (iii), there is a need for guidelines for work with portable systems. Such guidelines should contain:

- Technical "standards" for portable systems for professional use;
- Practical solutions for risk assessment and good practice for work with portable ICT systems, including training and qualification, support and work organisation;
- Recommendations, in particular for small enterprises without a specialized organisational background;
- Recommendations for corporate prevention culture including collective agreements.

Due to the restricted capacity to influence the technological development and use of portable ICT systems, the guidelines should concern not only employers, but also several other target groups:

- Employees;
- Suppliers of portable devices and systems;
- Suppliers of services (transportation, accommodation, support).

Enforcement

Irrespective of the option chosen, enforcement of legal measures would pose problems due to the fact that effective monitoring of work performed with portable systems is complicated. The labour inspectorates should pay more attention to monitoring and enforcement activities relating to OSH management of work with portable systems (e.g. the selection of appropriate systems, risk assessment, adapted organization of prevention). This, however, would be more effective in large companies. Small and medium enterprises without a specialized OSH section could be reached by information campaigns in cooperation with their sectoral organizations.

Besides monitoring and enforcement, labour inspectorates should contribute to the dissemination of guidelines and provide advice to employers.

To meet these demands, labour inspectorates should increase their own competence in the field of working with portable systems and intensify cooperation, for example, with sectoral organisations, in order to provide the employers and employees with adequate information and advice.

VI Discussion

The study shows that the occupational use of portable computing and communication devices continues to grow in terms of the number of users, occupational fields and activities, and the speed of technological advance.

A special problem here is the fact that the driving force behind the development of such devices and systems and the associated communication services is not usually occupational use but use outside work.

The needs of occupational use can only find expression in actual technology if users articulate their needs. However, in view of the pace of technological advance, users often have little understanding, beyond their own immediate experience, of the ergonomics and other health aspects of working with portable devices. Consequently, they find it difficult to tell manufacturers exactly what they want.

These needs could be formulated by OSH experts and laid down in regulations or guidelines and exercise influence in the form of "standards". The VDU Directive has so far performed this function well for stationary VDU workstations. However, in view of the rapid developments in technology and applications, we have to ask whether the best approach here really is relatively inflexible legislation or rather guidelines adapted to ongoing development and with detailed instructions for specific fields of application.

Nevertheless, it must be said that a number of basic requirements relating to VDUs from the VDU Directive are still absolutely applicable to mobile devices and are also realistic for portable devices. These requirements, e.g. relating to the depiction of characters on displays or the reflective properties of VDUs, do not lose their relevance for healthy ergonomics even if these facts are ignored by many new technical developments, such as the shiny surfaces of notebook screens. In any case, any new guidelines should explicitly refer to the requirements of the VDU Directive.

The analysis of the risks shows that these can only be assessed and addressed if the devices, the type and intensity of their use, and all the other conditions associated with their use (working environment, work organization, employee skill levels etc.) are given appropriate overall consideration.

We have tried to demonstrate that the specific health risks are varied and far-reaching but have a single common point of origin – working on location with portable computing and communication devices. It is often argued that the conditions in which work on location takes place are not monitored by the employer. The fact is, however, that it is precisely this technology that is increasing the degree to which employee performance, working location and work methods are monitored. If this is the case, it must then also be possible to protect employee health with the aid of this technology. In addition, it is crucial in this context that mobile employees have sufficient knowledge of the possible risks to their health and of the possible remedies. The employer can and must inform his employees accordingly. The study shows that even today basic recommendations can already be made for the protection of health from the ergonomic and psychosocial risks of working with portable computing and communication devices.

All the same, there is still too little knowledge available from specific and representative studies. The latter are essential for the drafting of evidence-based guidelines for specific tasks.

Whereas the requirements relating to these devices are still relatively invariant and can be defined accordingly, work activities with portable devices are hardly amenable to standardization because they take place at locations of a varied nature and are subject to changing external conditions largely beyond the control of both employer and employee.

On the other hand, these conditions depend to a certain extent on the type of activity, e.g. the use of notebooks by support technicians, of input devices in logistics and of displays in vehicles. The study contains a very extensive overview of current fields of application. For these various fields of application it is possible to issue more or less specific recommendations and principles for the use of portable devices.

What is essential is that companies whose employees use portable computing and communication devices on location make a point of familiarizing themselves with the health aspects of this work and organize the work and health protection measures accordingly. Guidelines must be made available to them for this.

In practice, OSH managers cannot themselves monitor activities with portable devices, but must concentrate instead on organizing work and health protection.

In doing so, they can refer on the one hand to the OSH Framework Directive, while at the same time working with guidelines containing the evidence-based state of science and technology in terms of risks and remedies.

They should participate in the development and dissemination of guidelines and, in this way, acquire the necessary expertise themselves and develop new methods for the indirect monitoring of OSH by focusing their attention on in-company processes, organization, skills and health protection culture.

VII Conclusions

1. The occupational use of computing and communications systems is continuing to grow in terms of:
- The number of users,
- The fields of application and activities
- New technologies.

2. The following terminology is proposed:
- "Mobile IT-supported work"
- "Mobile e-Worker"

This is because these two aspects combined – mobility and the use of portable IT – are the characteristic features.

3. Since activities in the various fields of application differ greatly in some respects and the distinction between blue- and white-collar activities is becoming blurred, categorization on the basis of the characteristics of the particular activity makes more sense for the identification of risks and taking preventive measures.

4. The health risks due to poor or maladapted ergonomics and psychosocial stress are varied and considerable. These can be acute dangers (accident risk, e.g. from the use of portable devices when driving) or the latent risks of chronic physical and mental illness. These are the result not only of the direct use of the devices but also, and more importantly, of the circumstances of device use.
The first standards, recommendations and principles can already be defined on the basis of the existing findings.

5. There is a lack of representative and specific studies on mobile IT-supported work. These are necessary so that evidence-based guidelines can be drafted and specific, targeted measures can be defined.

6. The employer can and must shoulder his responsibility for the safety and health of his mobile e-workers even when they work away from the normal base. OSH management must therefore be adapted accordingly. This includes risk assessment, the availability of suitable equipment and systems, technical and personal support, training employees to use the systems in a healthy way and an adapted health protection culture. Employers, and particularly small and medium-sized enterprises, as well as manufacturers of devices and providers of IT services need standards and generally accepted recommendations.

7. The OSH Framework Directive covers all occupational risks including all aspects of mobile IT-supported work in general. The VDU Directive is not applicable from the legal point of view, but many of its provisions are applicable in practice to portable devices and particularly the ergonomic requirements. Serving as the state of the art, these should also form the basis for possible "standards" for portable devices for occupational use.

8. There are three options for future OSH management:
- A new directive;
- Modification of the VDU Directive and the extension of its scope to cover mobile IT-supported work;

- No new or modified directive, but the drafting of guidelines and “standards”.

The last option would appear to be the best way of satisfying the needs of OSH in the mobile IT-supported work sector in the light of the speed of technological progress.

9. The most effective way to achieve compliance is for OSH authorities to concentrate on indirect monitoring by inspecting the way work is organized in companies. They should participate in the drafting of generally accepted evidence-based OSH management “standards” and guidelines and in their dissemination.

10. OSH management for mobile IT-supported work should facilitate a holistic approach in cooperation with other organisational management disciplines. This is the key factor in successfully enabling occupational safety and health in this new field.

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http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:299:0009:0019:EN:PDF

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List of Abbreviations

AmI	ambient intelligence
ASP	application service provider / providing
BISER	Benchmarking the Information Society: e-Europe Indicators for European Regions
CNET	www.cnet.com
CPU	Central Processing Unit
CSCW	computer supported collaborative work
DGB	Confederation of German Trade Union (Deutscher Gewerkschaft Bund)
DGUV	German Statutory Accident Insurance (Die Deutsche Gesetzliche Unfallversicherung)
EC	European Commission
E-commerce	Electronic commerce
EEC	European Economic Community
EEG	Electroencephalography
EU	European Union
EU10	Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Malta, Slovakia, Slovenia
EU15	European Union (15 countries: Belgium, Germany, France, Italy, Luxembourg, Netherlands, Denmark, Ireland, United Kingdom, Greece, Portugal, Spain, Austria, Finland, Sweden.)
EU25	European Union (25 countries: Belgium, Germany, France, Italy, Luxembourg, Netherlands, Denmark, Ireland, United Kingdom, Greece, Portugal, Spain, Austria, Finland, Sweden, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Malta, Slovakia, Slovenia)
EU27	European Union (27 countries: Belgium, Germany, France, Italy, Luxembourg, Netherlands, Denmark, Ireland, United Kingdom, Greece, Portugal, Spain, Austria, Finland, Sweden, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Malta,

	Slovakia, Slovenia, Bulgaria, Romania.)
EUROSTAT	Directorate-General of the European Commission, responsible for statistics
Euro zone/Euro area	Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Slovenia Luxembourg, Malta, Netherlands, Portugal, Spain.
FASTAP	the world's smallest keypad, formerly known as OneTouch
FIOH	Finish Institute of Occupational Health
FIZ-Technik	Fachinformationszentrum Technik; Centre for Professional Information (free translation)
GB	Gigabyte
GDP	gross domestic product
GPS	Global Positioning System
GVG	Gesellschaft für Versicherungswissenschaft und -gestaltung
ICT	information and communication technologies
INSP	database of FIZ-Technik
Internet	worldwide, publicly accessible network of computer networks using the Internet Protocol (IP)
IT	information technology
IST	Information Society Technologies
LCD	liquid crystal device
MID	mobile Internet device
Mobile eWorker	(physically) mobile worker using ICT systems with high intensity
MOSAIC	Mobile Worker Support Environments
MS	Member States (of European Union)
OSH	Occupational Safety and Health
PC	personal computer
PDA	personal digital assistant

PS	portable (computer) systems
QWERTY	modern-day keyboard layout on English-language computer and typewriter keyboards
RFID	radio-frequency identification tag
SIBIS	Statistical Indicators Benchmarking the Information Society
SMEs	small and medium-size enterprises
SoC	System-on-a-chip
SSCT-LCD	Surface-Stanilized Cholesteric Texture LCD
TEMA	database of FIZ-Technik
TFT-LCD	thin-film transistor LCD
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek; Netherlands Organisation for Applied Scientific Research
UK	United Kingdom
UMPC	ultra-mobile PC
USB	Universal Serial Bus
VGA	Video Graphics Array
VDU Directive	Visual Display Unit Directive
WWW	World Wide Web
ZIGUV	Zentrales Informationssystem der gesetzlichen Unfallversicherung, Central Information System of German Statutory Accident Insurance (free translation)

European Commission

The increasing use of portable computing and communication devices and its impact on the health of EU workers

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This report aims to shed light on the purported effects of portable computing and communication devices (hereafter called portable IT) on the health and safety of those workers that may be using them more frequently. In fact it is believed that this trend, rather than be attenuated, should increase since it is to be expected that, in its various forms and guises, the use of portable IT will become an unavoidable aspect of ever more professions/occupations. The various types of health effects due to portable IT use, both physical and psychological, are covered in the report.

In tackling this challenge the report tries also to characterise patterns of portable IT use among those occupations where it is supposedly more typical. Thus, types of work, working patterns, working environments, categories of workers and the possible disruption to personal life that the portability factor may bring about, are all aspects covered. A prediction of how will portable IT use evolve and the associated health problems to be expected is also included.

The public of this report are any interested parties such as employers and employee organisations and representatives, policy makers, managers and workers as well as health professionals, all of whom may find in the report interesting and new information that may help them understand the phenomenon better and make more informed choices.

Consequently, the report also includes options for management and legislation to try and compensate for the purported negative health effects of portable IT use.

This publication is available in printed and electronic format in English.

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