Harnessing Handheld Computing - Framework, Toolkit and Design Propositions

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Framework, Toolkit and Design Propositions

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Dedicated to Siri and to the memory of Birger and Gösta

Abstract

The rapid development of handheld technologies such as smartphones and personal digital assistants in recent years has created opportunities for the mobile workforce to take advantage of computerised information systems. To apprehend and harness the opportunities of computerised information systems implemented on handheld devices it is crucial to fully understand the user group and the handheld technology.

However, there is a lack of comprehensive frameworks and toolkits supporting designers of computerised handheld information systems for the mobile workforce. The aim of this dissertation is to address this issue by developing both a framework and a toolkit for use early in the design process.

To develop and evaluate the framework and the toolkit, various qualitative methods such as interviews, artefact studies, and experiments were applied for assessing both users' and designers' views on handheld computing. The analysis is made from a designers' perspective and based on the entities, user, application, context and technologies.

The proposed *accentuated factors framework* is a comprehensive framework of fifteen factors, evaluated and approved by experienced practitioners.

The *HISD Toolkit* presented is based on the accentuated factors framework and supported by the design propositions *Least Common Denominator*, *Flexible Forms, Tune-In* and *Defensive Design*, which are also presented in this dissertation.

The main implication for research is the use of the accentuated factors framework in analysis of handheld computing. The main implications in practice are the use of the HISD Toolkit in the design of handheld information systems, in the teaching of handheld computing, and in the evaluation of existing systems as in the procurement of computerised handheld information systems.

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The initial plan was to write a very short acknowledgement "To all involved – thanks!" However, as I realised in the end, that would be impertinent to those who have helped me in the challenge of writing this dissertation. Anders G. Nilsson, Markus Lahtinen, and Pär-Ola Zander provided invaluable support by offering suggestions for improvement, Nicklas Holmberg for multifaceted discussions on design science, and Paul Pierce coaching me in the final stages, I am in debt to you. Thanks to my colleagues at the Department of Informatics for appreciated comments, suggestions for improvement and interesting discussions regarding my research and science in general. Thanks to informants, anonymous reviewers and everyone else who supported me in this quest — To all of you, without your support this work would not exist.

Furthermore, there are four people who have had a particular impact on this work and to whom I owe my sincere gratitude. Sven Carlsson, as a remarkably knowledgeable supervisor, was always prepared with valuable suggestions. My co-supervisors Christina Keller and Stefan Henningsson inspired good ideas and were sounding boards for all my ideas and worries. Finally, Jonas Hedman, as a controversialist, hammered my ideas. You have changed from being colleagues to friends, and that is rare as I am very fastidious about whom to consider friend.

Finally and most important Cecilia, My, and Max—without you nothing else matters.

Loverslund, April 2012
Bo Andersson

"We apologise for the inconvenience" (Adams 2002, p. 642).

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PART ONE

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PART ONE

1 Introduction

This dissertation deals with design of computerised information systems implemented on handheld devices for the mobile workforce. It is based on the assumption that computerised handheld information systems for the mobile workforce have specific properties that ought to be managed in the design of those systems to harness the possibilities of computerised handheld information systems.

In this chapter, the rationale of this dissertation is presented as well as the research goals and key concepts. The chapter ends with a description of the internal structure of the dissertation.

1.1 Handheld computers – creating new opportunities

Things are changing in the landscape of information systems; one of these changes is handheld computing and in this realm the dissertation resides. This change is evidenced by the increasing number of handheld devices with capabilities to function as small-form computers reaching the market. These devices, often labelled *personal digital assistants* or *smartphones*, usually have two features in common: the ability to connect to wireless networks for data communication and the pocket-size format.

Keeping pace with the proliferation of these devices, wireless networks have been developed with greater geographical coverage and increased transmission rates. Taken together, these changes are the foundation of a technological shift with high expectations and alleged importance, see for example: Stafford and Gillenson (2003), Urbaczewski et al. (2003) and Sørensen (2011).

The aforementioned technological shift will likely affect a large group of users, and an indication of its importance to the field of information systems is its sheer mass. The number of connected devices compared to wired computers makes the mobile information systems field central, since the total number of handheld devices significantly exceeds the number of desktop computers, and this difference is increasing (Rupnik 2009). In 2008 the number of desktop computers in use (i.e., stationary wired computers) in the world was estimated to be 1 billion and expected to be 2 billions in 2014, this compared to the smartphone sales of almost 500 millions under 2011 and soaring (Goasduff 2012, Pettey 2011). Figures on sold units are difficult to translate to numbers of units in use; as a complement the number of mobile subscriptions can indicate the impact of mobile phones and installed devices. The number of subscriptions reached 6 billions under 2011 (Itu 2012). Connect this to the estimate that mobile phones will be replaced every 18 months with a newer and smarter mobile phone (Moll 2007); makes the mobile phones a significant platform for development of information systems.

The mobile workforce is also increasing globally. It is estimated that mobility continues to be enterprise-critical and that the mobile workforce will exceed 1.3 billion in 2015 (Crook et al. 2011). This workforce ability to use wireless communication will be even greater when the next generation of mobile data communication networks with transmission rates of up to 100 Mbit/s (in some circumstance up to 300 Mbit/s) is implemented in the mobile phone carriers' networks (Ericsson 2007). All these numbers and quantities indicate that the mobile field is large and expanding and will expand for a considerable time. This growth, in combination with the technological shift, creates opportunities for new user groups and new applications, thus making mobile computing an important subject for researchers and practitioners.

Arguments are put forward that the changes initiated by the increased possibilities of mobile computing are especially important for those who use mobile technologies in a work context. Furthermore, this user group is considered to be among those who have most to benefit from the increased opportunities of computerised handheld information systems (Cozza 2005, Sorensen 2011).

Two examples of successful implementations generating competitive advantage in this area are Nissan and HBOC. When the car manufacturer Nissan equipped its salesmen with handheld devices and connectivity to the current sales and inventory data, they showed increased efficacy by reducing the number of sales visits to obtain clearance for an order from an average of five to an average of three client visits. Furthermore, sales support could be reduced by 40%, thereby reducing the cost of information system ownership. McKesson HBOC, which is the largest pharmaceutical wholesaler in the US, invested about 400 million USD in an order- and stock-logistics system; 1,300 handheld devices were distributed in the organization and as a result productivity increased by 8% and the number of incorrect deliveries fell by 80% (Standage 2001). Further examples are improved supply chain management (Hanebeck and Tracey 2003) and improved internal information handling in the utility sector (Nah et al. 2005). Stories such as these portrays that mobile technology can create competitive advantages, and these examples may work as arguments for managers to approve investments in mobile technologies.

1.2 Handheld computing – something is still missing

The above claimed benefits can, however, be questioned and there is evidence that computerised information systems developed for the mobile workforce do not meet expectations and fail to support the mobile workforce. These studies range from changes in organisational and social settings (Allen and Wilson 2005) to changes in work practice (Er and Kay 2004, Er and Kay 2005, Norman and Allen 2005) and problems related to lack of user involvement (Marcus and Gasperini 2006), misalignment between implemented and real work processes (Andersson 2008) and how to support collaboration and mobility with mobile technologies (Luff and Heath 1998). What these studies have in common is that the developed systems did not take into account the properties of the mobile workforce and the properties of the mobile technologies. This raises questions about how handheld information systems should be designed to take these aspects into account. Can the answer be that computerised handheld information systems requires specific design considerations and that the knowledge base applied in design and development of desktop computing is not always applicable to computerised handheld information systems for the mobile workforce? As Fällman puts it: “What we think of as mobile information technology is related to and draws on traditional ideas of desktop computing in a multitude of ways. These dependencies are not only beneficial and desirable but also carry with them restrictions and hidden assumptions that suppress mobility in different ways (Fällman 2003, p. 65)”

That is, when thinking of desktop computing, in most cases the supposed environment is the office. The desktop as a schemata, or framing, in design of information systems is a mindset present in a multitude of aspects; the computer resides on the desk and is built for desk use. For example; the interface of the screen is a virtual replica or abstraction of the physical desktop; the interface tries to mimic the familiar workspace with metaphors such as the recycling bin; the email icon in form of a letter; the logical structure of the file system comparable with a binder; and so forth. A framing, or a mindset, that can be considered as a design paradigm within system development.

Drawing on Fällman's (2003) argument that the desktop metaphor, in several aspects, is not a suitable mindset when it comes to mobile computing, it is of value to discuss an alternative mindset. I agree with Fällman's argument and believe that handheld computing would benefit from another mindset, coining the properties of the handheld and field usages as part of the workplace instead of the office and the desk, a view supported by, among others: B'Far (2005), Dahlbom and Ljungberg (1998), Lyytinen and Yoo (2002a), Zeidler, Kittl and Petrovic (2008), and Zheng and Yuan (2007).

The existing frameworks—such as those of Zheng and Yuan (2007), which consist of the entities *mobile workers, mobile context*, *mobile tasks*, and *mobile technologies* to describe differences between stationary and mobile context—are typically high level. For more example; when Kakihara and Sorensen's (2002) discuss mobility and include *temporal*, *spatial*, and *contextual mobility* as mobility phenomena; Tarasewich (2003) suggestions that context be divided into three categories: *activities*, *environment*, and *participants*. Furthermore, Perry et al. (2001) extended view of the concepts of *anywhere* and *anytime* that broadens the view on mobility; or work on m-commerce as by Chen and Nath (2004) or Ngai and Gunasekaran (2007).

These descriptions are important contributions to the field of handheld computing in describing what mobility is, however, one limitation is that the frameworks are not specifically developed to support the design of computerised handheld information systems and not easily actionable upon. A tool or design principle based on these descriptions or frameworks is lacking. A second limitation to consider is that, by and large, the research on handheld computing is scattered: A more comprehensive description would be beneficial for information system designers. This is partly due to the multifaceted nature of handheld computing (as will be shown in section 2.3). A third limitation is the amount of research on the mobile workforce. The majority of research has been focused on the customer, with less emphasis on the mobile workforce. However, the mobile workforce resides in a specific environment, and arguments are raised that there is a need for further research into applications and systems supporting the mobile workforce and a need for more empirical research, see for example: Andersson (2007), Andersson (2010), Andersson (2012b), Barnes (2003), Basole (2008), Fouskas et al. (2005), Krogstie et al. (2004), Lyytinen and Yoo (2002b), Mcintosh and Baron (2005), Scornavacca et al. (2006), Varshney (2003) and Varshney et al. (2004).

1.3 Dissertation aim

A basic assumption in this dissertation is that computerised handheld information systems have specific properties, compared to desktop computing, that ought to be managed in the design of those systems. For example differences between office context and mobile context: between expected computing tasks for office work and mobile work; between desktop technologies and handheld technologies (B'far 2005, Fällman 2003, Zheng and Yuan 2007). These are examples of differences that affect designers and developers of computerised handheld information systems. As indicated in the introduction, and as will be shown further on, there is a lack of comprehensive frameworks and thereto-related tools supporting designers of computerised handheld information systems to manage the specific properties of handheld computing, especially for the mobile workforce. Although there exists a plethora of design guidelines how to deal with individual properties, such as the small screen interface, the scattered nature of the design guidelines reduces their usefulness. These design guidelines are chiefly delivered from the HCI-field doing research regarding individuals' relation to the technological interface (Sorensen 2011), and not to the multifarious environment that the workforce settings constitute. To harness the opportunities and complexity necessitates a research agenda that encompasses several disciplines and involves multiple levels of analysis, and "that IS researchers are uniquely positioned to understand how to integrate various technological, social, and managerial issues while designing, building, and managing such environments" (Lyytinen and Yoo 2002b, p. 378).

A comprehensive approach is valuable in order to design appropriate computerised handheld information systems (Sorensen 2011) and the central thesis in this dissertation is that a comprehensive approach towards management of the specific properties of handheld computing is necessary in order to design appropriate computerised handheld information systems.

The aim of this dissertation is to address this lack of a comprehensive approach by developing a comprehensive framework and a toolkit derived from the comprehensive framework.

The advantage of a comprehensive framework, used in analysis and early design of computerised handheld information systems, is the reduced risk of missing out important aspects of handheld computing.

The advantage of a toolkit is the conversion of the theoretical framework to a method that can be utilised by designers in design and development of computerised handheld information systems.

An ambition of this dissertation is to identify both theoretical and practical implications and to inspire designers and other stakeholders in the design of computerised handheld information systems for the mobile workforce. Therefore is design science seen as an appropriate research approach, i.e., design science with utility as a goal, see for example: Gregor (2009), Hevner and Chatterjee (2010), Hevner et al. (2004) and Walls et al. (1992).

1.4 Key concepts and definitions

To facilitate reading, an explanation of key concepts used in this dissertation follows below.

Regarding *handheld computing* versus *mobile computing*. The concept studied in this dissertation is, in most existing research, labelled as *mobile computing* or *mobile information systems* even though it most often regards *handheld computing* or *handheld information systems*. This may cause uninvited ambiguity in the treatment of existing research. Evidently, *mobile computing* or *mobile information systems* may be valid labels: “Mobile computing systems entail end-user terminals that are easily movable in space, are operable independent of location, and typically have access to information resources and services. As in conventional information systems, users share data and are able to perform collaborative work, either synchronously or asynchronously, with other users” (Krogstie et al. 2004, p.223). This definition includes *handheld* devices and related information systems and applications. Though, it also includes laptops, tablet PCs, vehicle-mounted computers, etc., making the label of *mobile* too broad to be useful in the context of this dissertation. Hence, *handheld computing* or *handheld* *information systems* will, where appropriate, be used in this dissertation to clarify the technological platform and the expected use situation.

Furthermore, *handheld information system* should be understood as computerised information systems that are implemented on handheld devices. In this dissertation the implemented system is an interface to a backbone system as an enterprise resource planning system or likewise. Here a distinction between *handheld information systems* and *handheld computing* is appropriate. As implied in the previous section, handheld information system are an artefact per se, meanwhile *handheld computing* should be understood as an overarching concept related to the *use* of a handheld information system. That is, the user does use an information system to compute information.

Accentuated (i.e., more notable (Sinclair 1995)) should be interpreted either as a factor that already exists but has *gained greater importance* or exists but has *changed its properties* or as a *new factor* entering the system development domain when a mobile system is to be built. This leaves the overlapping factors between mobile and stationary computing out of scope. That is, factors that are equivalent in both environments are excluded.

Framework should be interpreted as something that works as a demarcation, a separations of concerns. In this dissertation, the framework is theory driven, mainly descriptive, whereas some casual relations can exist (Miles and Huberman 1994, Palvia et al. 2006). Inside the framework reside factors specific for handheld computing.

Factor should be interpreted as a feature or circumstance contributing to or affecting the developmental efforts, i.e., "a factor is one of the things that affects an event, decision or situation" (Sinclair 1995, p. 595). The *small form factor* and *wireless connectivity* are examples of factors in mobile computing. Factors can be described by their properties such as *small screen* or *varying transmission speed*.

Toolkit should be interpreted as a set of resources used for a particular purpose (Stevenson 2010).

In conjunction with framework and toolkit, *comprehensive* is mentioned and should be interpreted as *including or dealing with all or nearly all elements or aspects of something* (Stevenson 2010) with emphasis on *nearly all aspects.* Guaranteeing full coverage on a framework is problematic due to the interleaved properties with other areas such as desktop computing. Furthermore, the speed of change in the field of information systems makes it problematic to develop a perfectly comprehensive framework.

It is argued that systems should be *appropriate*, and this should be interpreted as *suitable or proper in the circumstances* (Stevenson 2010). That is, due to the specific context, certain needs and constraints may apply that are not transferrable to other systems and contexts.

A frequent used term in the text is *manage* and its variants. It should in the most cases be interpreted as control, handle, master; cope with, deal with (Stevenson 2010), hence not interpreted as synonym for executive or be in charge of .

Harnessing should be interpreted as controlling and utilising a resource, as in "harnessing solar energy" (Stevenson 2010).

The rationale for declare *early design* is that the framework and toolkit are designed to be used in the first step of design, in the requirement engineering phase (Dorfman 1990, Sommerville 2011).

The terms *stationary* and *desktop* are in need of clarification. These two terms are often used as synonyms or equivalents. However, on one hand, *stationary* implies immobility, and the opposite would be *mobile*. *Desktop*, on the other hand, implies an environment, both in interface design and a workplace environment. Furthermore, both *stationary* and *desktop* may rule out laptops and vehicle-mounted computers. Deciding to use only one of the two results in losses in accuracy, while using both causes ambiguity; there is no best-decision rule. In the forthcoming text the term *desktop* computing will be used if there are no problems with interpretation and should be considered as more or less equivalent with *stationary* computing. However, in those cases where it has importance, for example when discussing mobility per se or in quotes, stationary will be used.

Most studies of the mobile workforce involve white-collar workers, and these are expected to gain the handheld technologies (Areskoug 2003). In this dissertation the workforce is the *blue-collar workers*. "A blue collar worker is an employee who performs manual or technical labour, such as in a factory or in field environment in contrast to white collar workers, who do non-manual work generally at a desk" (Valiente 2006a, p. 14). See section 2.2.2 for a more elaborated discussion on the user at hand.

Regarding the unit of analysis, the phenomenon studied includes the IT-artefact *and* the actual context. A unit of analysis corresponding to the concept of *IT-reliant work system*, "work systems whose efficient and/or effective operation depends on the use of IT", is used (Alter 2003, p. 367). Hence, the usage and the context are equally important, that is: "No prefabricated commercial software product is an information system as such. An information system cannot be bought, only software and hardware (and possibly data) to be used in its implementation can be bought"(Iivari 2003, p. 571). Following Iivari (2003) and Alter (2003), the unit of analysis in this work is the *IT-reliant work system*, and in this dissertation it excludes studies outside the business domain.

1.5 Delimitations

When studying new technologies, such as handheld computers and use thereof, the scope can be broad. It can span from ingenious contraptions to in-depth ethnographical studies investigating the users' perceptions of technology. Hence, an account of interesting topics, though outside the scope of this dissertation, follows below.

Regarding ingenious contraptions, considerable amounts of innovative apparatus have been developed to manage different factors of handheld computers. These include for example external mounted scrolling devices to manage problems displaying large objects on a small screen (Fallman et al. 2004), external one-hand-manoeuvred keyboards to manage small keyboards (Lyons et al. 2006), multimodal interfaces combining sound and keystrokes in an advanced combination (Oviatt et al. 2000), and calm technologies as walls mediating communication (Streitz et al. 2005). These may be interesting and important contributions, but I argue that in most cases these innovations, at the time of writing, are not commonplace or available on standard devices in the market. In fact, some of these innovations may never reach the market and will remain only as interesting concepts. As a consequence, designers have to solve problems with the technologies that are already available off the shelf in the market. In this dissertation, the off-the-shelf devices are the hardware upon which applications will be built.

Studies of a more ethnographical approach are valuable in order to understand mobility as a phenomenon. They may investigate how drivers use mobile phones while driving (Esbjornsson et al. 2007) or ski instructors' perceptions of mobile communication technologies (Weilenmann 2001). Nonetheless, it is not straightforward for a designer to translate ethnographically derived descriptions into design. My ambition is to go beyond descriptions and to offer suggestions to manage aspects that may be ethnographically derived.

As mentioned in the key concepts section, the study resides in the business domain where, for example, business-to-employee and employee-to-employee relations are of interest, and leisure applications and business-to-consumer relations are of less interest. Hence, the App-revolution with App Store (Apple), Android Market (Google), Marketplace (Microsoft) and App World (Research in Motion) where the majority of applications today are for leisure applications etc., are partly out of scope. Of course, the rise of Apps has an impact on the mobile industry at large. However, design frameworks and toolkits for design of handheld information systems for the mobile workforce are independent of realising technologies, and aspects to consider remain mostly indifferent to the advent of Apps. In those cases where Apps, App development, App markets, and related technologies are relevant they will be discussed.

1.6 Structure of the dissertation and use of papers

In this section the logical structure of the dissertation is described; the content in the paper collection is presented; and the relation between papers is portrayed.

This dissertation is divided into two parts, where the first part comprises the summarising chapters of the dissertation, the cover. The structure of part one consists of five chapters (illustrated in figure 1). The second part of the dissertation contains the collection of papers.

My ambitions is to present a cover that can be read and understood without reading the papers; relieving the reader from frequently shifting back and forth between cover and papers. Therefore, some redundancy exists in the cover. Regarding cover versus papers, the main decision rule applied is that only the results of papers are inserted into the cover. Still, to increase transparency regarding method and empirical settings, the method and the cases are described in greater detail in the cover compared to the papers.

In figure 1, the division between papers and cover are illustrated and, as shown, some sections are based on papers (more specific, sections 2.7, 4.1, 4.3, and 5.3), whereas other sections are only represented in the cover. For example, the proposed toolkit, being an aggregation of the theoretical framework and empirical findings, is not presented in any paper, but is presented in section 4.2.

Concerning the content in chapters, the first chapter is an introduction to the dissertation; it sets the backdrop with motive, aim, key concepts, limitations and structure. After reading chapter one, the reader should agree upon the rationale for the dissertation.

The second chapter validates the arguments put forth in chapter 1 by setting the scene; and reviews prior research regarding handheld computing. In this chapter a tentative framework is developed based on available research. Though also presented in paper 2, in this chapter is a more detailed account of the factors put forth, this because the importance of the tentative framework. After reading chapter 2 the reader should be familiar with handheld computing in general; the accentuated factors of handheld computing; and knowledge gaps in relation to the accentuated factors (based on paper 1).

In the third chapter, my pre-knowledge is described whereas my work experience influences motive, approach, and method. The research approach and method are also explained in greater detail in this chapter, compared to the papers. After reading chapter three, the reader should be more familiar with the scientific approach and method underpinning the empirical work, compared to only reading the papers. Hence, being able to make judgement on the trustworthiness of the study.

The fourth chapter presents the contribution made in the shape of analytical framework and artefacts, such as the extended and evaluated comprehensive framework based on papers 2 and 3; a toolkit for design of handheld information systems; and design propositions via papers 4, 5, 6, and 7.

The fifth chapter summarises the knowledge contribution and presents reflections on research quality, retrospection on developments in the field of handheld computing research based on paper 8, suggestions for future research, and finally concluding remarks on what has been accomplished in this dissertation.

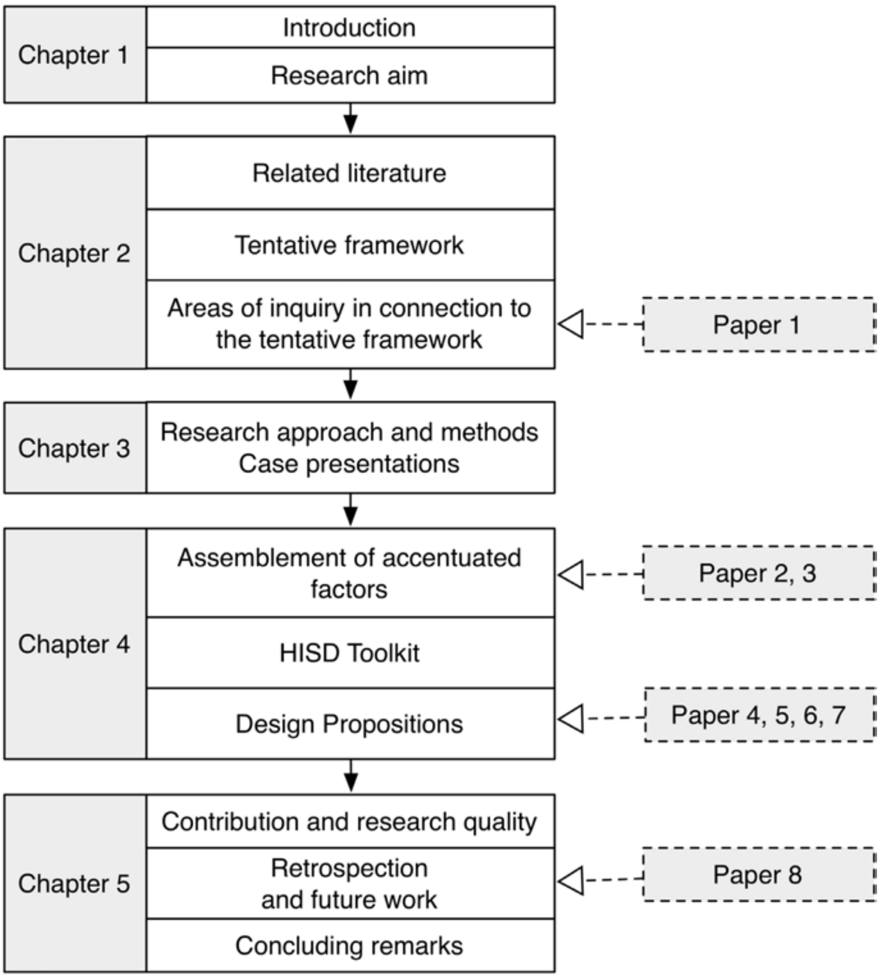

Figure 1. The figure is a simplified illustration of the main structure of Part One of the dissertation and where the papers are used in the cover. The arrows point towards where the contributions of papers chiefly are represented in the cover.

1.7 Collection of appended papers

Below is the collection of appended papers presented. All papers are full papers and all papers are blind reviewed. Paper 1-6 and 8 have been presented at conferences and published in proceedings. Paper 7 is recently reviewed and accepted, however not yet presented nor published. The papers can be found in Part Two of the dissertation. In addition to these papers, the author has written six previous and supplementary papers as part of the cumulative process of presenting and enhancing the research related to this study. Those papers are presented in the "additional publications" row. Below is a description of the structure applied to present the papers (table 1).

Table 1. Legend of the following eight tables describing the papers used in this dissertation.

Aspect	Description
Reference	Bibliographical reference
Objectives	The objectives of the paper
Method	The applied method in the paper
Concepts in paper	The main concepts or constructs of the paper
Research contribution	Overall contribution to an external audience
Contribution of paper to the dissertation	The paper's specific contribution to this dissertation
Placement in dissertation	Where the content of paper is applied in Part One of the dissertation. The full paper is located in Part Two.
Author contribution	The dissertation author's contribution to the paper.
Additional publications	References, if any, to other publications by the dissertation author related to the specific paper. Abstract are located in appendix.

1.7.1 Paper 1

Table 2. Description of content and contributions in paper 1.

Aspect	Description
Reference	Andersson, B. (2010).*Mobile computing from a developer's perspective: a 10-year review, 1999–2008.* Proceedings of the 9th International Conference on Perspectives in Business Informatics Research. Rostock.
Objectives	The purpose is to investigate areas of inquiry from a design science perspective by examining how factors in the tentative framework have been managed in 26 journals.
Method	Twenty six high-ranked journals were examined, and 102 publications were selected between 1999 and 2008 according to a) accentuated factor, b) descriptive or prescriptive approach, c) organisational settings such as B2B, B2C, or N/A. The results were then aggregated and analysed.
Concepts in paper	The research model as the tentative framework of accentuated factors, design science as a research approach, and organisational settings
Research contribution	The results displayed an uneven distribution of publications managing accentuated factors; the main focus was on context awareness, small form factor-interface, varying connection, and hardware capacities, while supporting technologies, task dependencies, and field-use conditions were hardly researched. Regarding descriptive or prescriptive approaches, there was an even distribution, but regarding organisational settings the results showed that research on the mobile workforce (B2E) was under-represented with 14.7% appearance in the selected publications.
Contribution of paper to the dissertation	Based on previous research, a tentative framework of accentuated factors is put forth. The paper uses this tentative framework as a research model, and the results act as guidance for a) the design propositions in papers 4, 5, 6, and 7, and b) the starting point for the retrospection describing the progress of the field discussed in conjunction with paper 8.
Placement in dissertation	The result from the paper is applied at the end of chapter 2 where it acts as a departure for the rest of the dissertation.
Author contribution	The dissertation author is the sole designer and author of the paper.
Additional publications	Andersson, B. (2007). *Mobile computing investigated: A review of what has been done in the domain of mobile computing research*. Proceedings of the NOKOBIT 2007 Conference, Oslo. Abstract in appendix 7.1.

1.7.2 Paper 2

Table 3. Description of content and contributions in paper 2.

Aspect	Description
Reference	Andersson, B. and Henningsson, S. (2011). *Accentuated Factors of Handheld Computing.* Proceedings of the 20th International Conference on Information Systems Development, Edinburgh.
Objectives	The objective is to develop a descriptive and analytical framework for handheld computing.
Method	The empirical data are based on semi-structured interviews with thirteen informants with experience of design and development of handheld applications.
Concepts in paper	Accentuated factors framework, information systems for the mobile workforce, handheld computing devices, framework evaluation
Research contribution	The paper presents a comprehensive framework for accentuated factors usable as a) an analytical tool in research on handheld information systems, b) a design framework to capture the central factors of handheld computing for the mobile workforce, and c) an evaluation tool in procurement of handheld information systems for the mobile workforce.
Contribution of paper to the dissertation	The framework is the foundation of a) the analytical framework used in the HISD Toolkit, b) the analytical framework used in the literature review, and c) the framework used in identifying relations between factors.
Placement in dissertation	The results from the paper are applied in a) the analytical framework in section 4.1, b) the presentation of the HISD Toolkit in section 4.2, c) the literature review in paper 8, and d) as the theoretical framework in paper 3.
Author contribution	The dissertation author is the main contributor to the paper and wrote the main part of the text and carried out the empirical data collection and analysis of data. Both authors read and approved the final manuscript.
Additional publications	Andersson, B. and Henningsson, S. (2010b). *Use of mobile IS: new requirements for the IS development process*. In: Isomäki, H. and Pekkola, S. (eds.) Reframing Humans in Information Systems Development. London, Springer. Abstract in appendix 7.1. Andersson, B and Henningsson, S (2010a). *Developing Mobile Information Systems: Managing Additional Aspects*. European Conference on Information Systems (ECIS), Pretoria. Abstract in appendix 7.1.

1.7.3 Paper 3

Table 4. Description of content and contributions in paper 3.

Aspect	Description
Reference	Andersson, B. (2012a). *Enhancing the Accentuated Factor Framework: Dependencies Between Factors.* Accepted, and will be presented at the 20th European Conference on Information Systems, Barcelona.
Objectives	To further extend the analytical framework of accentuated factors into a describing and explaining framework.
Method	The results are based on a total of 32 interviews: sixteen interviews with experts, seven interviews with developers, and nine interviews with the users of a service order system. Seventy-one weekly workshops were made on the development of a mobile IS.
Concepts in paper	Accentuated factors framework, internal dependencies between factors
Research contribution	A theory describing the internal dependencies between the factors in the accentuated factors framework and the enhancement of the comprehensive accentuated factors framework
Contribution of paper to the dissertation	The result is an important part of the HISD Toolkit, informing designers of the most central and influential factors that must be considered early in design. Short descriptions of the internal dependencies are also an important part of the HISD Toolkit by displaying design insights.
Placement in dissertation	In the accentuated factors framework in section 4.1 and the HISD Toolkit in section and 4.2.
Author contribution	The dissertation author is the sole designer and author of the paper.
Additional publications	N/A

1.7.4 Paper 4

Table 5. Description of content and contributions in paper 4.

Aspect	Description
Reference	Andersson, B. and Hedman, J. (2007b). Developing m-Services: Lessons Learned from the Developer's Perspective. *Communications of the Association for Information Systems*, 20, 605–620.
Objectives	To present learning experiences from the development of a messaging system connecting desktop computers to the mobile operators' networks
Method	The main method used was participating in the development process as part of the development team. Other methods included interviewing the developers and mobile operator staff and analysing internal documents and system interface documents published by the mobile operator. As a complement, twelve semi-structured interviews were made.
Concepts in paper	Mobile operator platforms, platform proliferation, differences in standard interpretation, differences in device interpretation of standard picture files
Research contribution	Suggestions on how to manage problems related to lack of standards and platform variation with "least common denominator" strategies
Contribution of paper to the dissertation	The suggestions are formulated as design propositions to manage the factor *platform variation* and as design insights in the HISD Toolkit.
Placement in dissertation	The design proposition in section 4.3.1 and in the HISD Toolkit in section 4.2.
Author contribution	The dissertation author is the main contributor to the paper and wrote the main part of the text and carried out a substantial part of the empirical data collection and analysis of data. Both authors read and approved the final manuscript.
Additional publications	Andersson, B. and Hedman, J. (2006). *Issues in the Development of a Mobile-Based Communication Platform for the Swedish Police Force and Appointed Security Guards*. Third International Conference on Information Systems for Crisis Response and Management, New Jersey. Abstract in appendix 7.1. Andersson, B. and Hedman, J. (2007a). *Developing m-Services; lesson learned from the developer's perspective*. Global Mobility Roundtable, Los Angeles. Abstract in appendix 7.1.

1.7.5 Paper 5

Table 6. Description of content and contributions in paper 5.

Aspect	Description
Reference	Andersson, B. and Carlsson, S. A. (2009). *Designing for Digital Nomads: Managing the High Reliance on Single Application*. Proceedings of the Global Mobility Roundtable, Cairo.
Objectives	To present the learning experience from a study on the usage of a computerised service order system and to present solutions on problems related to high reliance on information systems
Method	Reading and analysing manuals, handbooks, and teaching materials—a total of 250 pages. Eight hours of observations and nine semi-structured interviews were carried out with users and managers.
Concepts in paper	The user category digital nomad, member of the truly mobile workforce, information system dependencies
Research contribution	Presenting the concept of truly mobile users, the circumstance of high reliance on information systems, and a design proposal to manage this reliance
Contribution of paper to the dissertation	Extension of the framework with the factor IS dependencies and a suggestion on how to manage this factor by the design propositions *flexible forms;* furthermore, design insights in the HISD Toolkit
Placement in dissertation	The design proposition Flexible Forms in section 4.3.2 and in the HISD Toolkit in section 4.2.
Author contribution	The dissertation author is the main contributor to the paper and wrote the main part of the text, carried out the empirical data collection, and analysed the data. Both authors read and approved the final manuscript.
Additional publications	Andersson, B. (2008). *About Appropriation of Mobile Applications - The Applicability of Structural Features and Spirit*. Proceedings of the 16^{th} European Conference on Information Systems, Galway. Abstract in appendix 7.1.

1.7.6 Paper 6

Table 7. Description of content and contributions in paper 6.

Aspect	Description
Reference	Andersson, B. and Keller, C. (2010). *Harness Mobility: Managing the Off-Task Property.* Proceedings of the International Conference on Design Science in Information Systems and Technology, St. Gallen.
Objectives	The objective of this study was to present a design of an artefact and a design theory using location awareness to relieve the user from administration tasks.
Method	Attending a presentation of a logistic system, three semi-structured interviews with the system developers of duration 60–120 minutes each, and studies of online material. Complementary information was gathered by telephone interviews.
Concepts in paper	Members of the truly mobile worker user group, interaction patterns, off-task use patterns
Research contribution	A design proposal based on market pull; the design proposal for Tune-In and the elaboration of off-task usage patterns as an instance of Interaction Patterns
Contribution of paper to the dissertation	Enforcement of the factor Interaction Patterns, presentation of a design proposition to manage interaction patterns—*Tune-In*—and design insights in the HISD Toolkit
Placement in dissertation	The design proposition Tune-In in section 4.3.3, and in the HISD Toolkit in section 4.2.
Author contribution	The dissertation author is the main contributor to the paper and wrote the main part of the text, carried out the empirical data collection, and analysed the data. Both authors read and approved the final manuscript.
Additional publications	N/A

1.7.7 Paper 7

Table 8. Description of content and contributions in paper 7.

Aspect	Description
Reference	Andersson, B. (2011). *Harnessing Handheld Computing – Managing IS Support to the Digital Ranger with Defensive Design.* Proceedings of the International Conference on Design Science in Information Systems and Technology, Milwaukee.
Objectives	To evaluate to what extent design considerations in the design of a logistic system have minimised alleged problems concerning support to the outbound user.
Method	Attending a presentation of a logistic system, observation of the use of a logistic backend system, five semi-structured interviews with the system developers of duration 60–240 minutes each, and studies of online material
Concepts in paper	Digital ranger, mobile workforce, support issues, the design proposition defensive design
Research contribution	Introducing the digital ranger as a user category, introducing support as a factor to consider in handheld computing, presenting a design proposition to manage support for the digital ranger
Contribution of paper to the dissertation	The support issue is identified as an important factor and added to the accentuated factors framework. The design proposition of defensive design is put forth as an example to manage support of the digital ranger. Finally, design insights to HISD are made.
Placement in dissertation	The design proposition Defensive Design in section 4.3.4 and in the HISD Toolkit in section 4.2.
Author contribution	The dissertation author is the sole designer and author of the paper.
Additional publications	N/A

1.7.8 Paper 8

Table 9. Description of content and contributions in paper 8.

Aspect	Description
Reference	Andersson B. (2012b). *Handheld Computing from a Designer's Perspective: A 10-year Review - 2001–2010*. Proceedings of the 45th Hawaii International Conference on System Sciences, Maui.
Objectives	To follow the tradition within the field of information systems research by examining the relevant literature with the purpose of gaining a better understanding of the present situation in the field
Method	Thirty one high-ranked journals and major outlets of mobile computing between 2001 and 2010 were examined, and 634 publications were selected for further examination. Eighty two publications matched the selection as a) dealing with mobile or handheld computing, b) belonging to design approach V, according to Gregor (2006), c) managing an accentuated factor, and d) having organisational settings such as B2B or B2E.
Concepts in paper	The comprehensive framework put forth in paper 2, mobile handheld computing, design science, and organisational settings
Research contribution	This is a traditional research overview describing the state of handheld computing research and suggestions for improvement regarding knowledge gaps in handheld computing research. The organisational settings such as B2B and B2E are less favoured, with coverage of 13.4%. The factors field-use conditions, support issues, supporting technologies, and time critical were also less favoured, with 0% coverage.
Contribution of paper to the dissertation	The content of the paper in conjunction with the first literature review presented in paper 1 provides a basis for retrospection on how the field has evolved during the last years.
Placement in dissertation	Retrospection in chapter 5.
Author contribution	The dissertation author is the sole designer and author of the paper.
Additional publications	N/A

1.8 Internal relation between papers

Below is an outline of how the different papers relate to each other, also illustrated in figure 2.

Paper 1 is a quantitative review (based on the tentative framework proposed in chapter 2) that identifies the degree to which the factors in the tentative framework have been researched. Hence, suggesting fruitful avenues for further studies on certain factors (see section 2.7 and Part Two).

In paper 2 the comprehensive accentuated factor framework is put forth. It is based on prior research, case studies and is evaluated by practitioners with experience of design and development of handheld information systems (see section 4.1.4 and Part Two).

Paper 3 is a direct extension of paper 2. It extends the accentuated factors framework presented in paper 2 by describing internal dependencies between factors and enhancing the framework from an *analytical* to an *explaining and predicting* theory (see section 4.1.5 and Part Two).

Papers 4–7 put forth design propositions based on empirical findings in case studies. In the literature review in paper 1, some under-reached factors were identified, i.e., no or few design suggestions were found that managed these factors. In order to fill knowledge gaps relating to these factors and to complement the toolkit, design propositions on how to manage specific factors in the toolkit are presented (see section 4.3 and Part Two).

Finally, paper 8 presents an updated literature review. It relies in part on an improved version of paper 1. It is based on the accentuated factor framework put forth in section 4.1 and paper 2. The results from this review are compared to those in paper 1 in order to discuss progress made within the field of handheld computing.

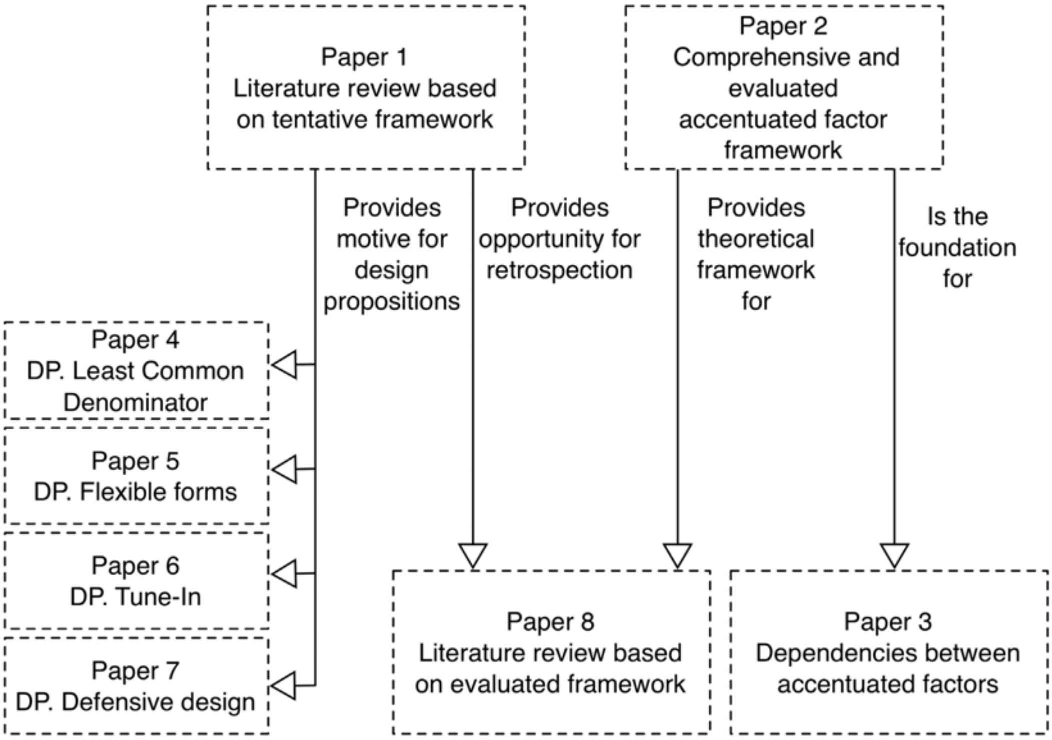

Figure 2. The arrows illustrate the main relation between the papers and are directional to describe the order in which the papers relate to each other. For example, in paper 1 knowledge gap are identified and provide motive for design propositions that fill these knowledge gaps (paper 4-7). The framework in paper 1 is updated and applied in paper 8, hence making a comparison possible. Paper 2 put forth a framework of 15 factors and these factors are part of the theoretical framework use in paper 8. Likewise, the 15 factors put forth in paper 2 is the theoretical framework in paper 3.

1.9 Contribution in chapter 1

The main contribution from this chapter is that after reading it, the reader should have an understanding of the rationale for the dissertation: and to have an idea of what the following parts and chapters will provide.

2 Handheld computing in literature

The main purpose of this chapter is to review the phenomenon of handheld computing. It starts with a review of the technology and user, which acts as a backdrop to the accentuated factors framework. This followed by a review on available research in order to assemble a tentative set of accentuated factors. Finally, the need for further studies related to the assembled set of accentuated factors is identified.

2.1 Setting the scene - the technological platform

As mentioned in the introductory chapter, more and more devices in the form of personal digital assistants (PDAs) and smartphones have entered the market, many with the capacity to function as small computers, however, with variations in terms of performance and size. The carriers' network has also grown in geographical coverage and transmission speed. Below, the growth of handheld technologies is demonstrated.

2.1.1 The evolution of handheld technologies

When the first devices entered the market, a handheld computer was synonymous with a PDA, an advanced electronic calendar without network abilities. In May 1983, Casio launched its PF-3000 (figure 3), considered to be one of the first PDAs, a "digital diary" with calculator, built-in telephone book, schedule, and memo functions. According to Casio, the PF-3000 was a result of technological advancements in hardware technology—from transistors to integrated circuits and large-scale integration, and from nixie tubes to liquid crystal display—which meant that smaller, more powerful devices could be built (Casio 2011).

Figure 3. The Casio PF-3000 Digital Diary launched in 1983 and considered one of the first PDA's (picture Pdadb (2011b)). In this picture with its foldable plastic cover.

In 1984, Psion launched the Psion Organiser (figure 4), a handheld device with applications such as calculator, database, clock, diary, phonebook, and synchronisation ability; significantly, it was programmable via Open Programming Language. This programming ability opened up a range of business applications, such as Marks and Spencer's shop floor administration and governmental use by the UK Department of Employment Services, and various military applications (Bioeddie 2006).

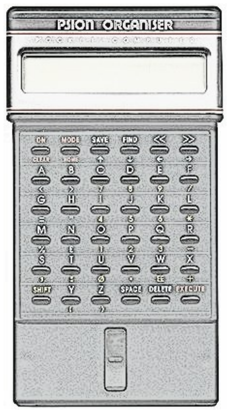

Figure 4. The Psion Organiser, launched in 1984, was among the first programmable handheld devices (picture Bioeddie (2006)).

In the 90s, a range of mobile devices reached the market. In 1993, the Apple Newton MessagePad 100 was launched, equipped with touch screen, handwriting recognition, wireless communication, extension slots, virtual keyboard, and a range of applications such as notes, names, dates, calculator, conversion calculators, time-zone maps, etc. (figure 5). The modern PDA had reached the market, and although the computing capacity was less than that of devices in 2011, the main functionality was the same (Pdadb 2011a).

Figure 5. The Apple Newton MessagePad 100, launched in 1993. This is often considered the first modern PDA with touch screen and a range of applications (picture Pdadb (2011b)).

In 1996, Nokia launched the 9000 Communicator, a mobile phone with most of the features of a PDA (figure 6). Now the PDA and the mobile phone had merged into what is now labelled as a *smartphone*, a handheld computing device that could benefit from the networks of mobile operators – not only WiFi networks. The 9000 Communicator was foldable and equipped with a large LCD screen and a QWERTY keyboard (Gsmarena 2011).

Figure 6. The Nokia 9000 Communicator, launched in 1996. Being a merger of a mobile phone and a PDA, it is an example of an early smartphone. To the right, the phone is up folded and the extended screen and keyboard is visible (picture Pdadb (2011b)).

At the time of writing this dissertation, pure play PDAs have more or less disappeared from the market and have been replaced by the smartphone; more or less only special purpose PDAs remain.

Today there is a plethora of manufacturers launching smartphones, for example: Apple, Nokia, RIM and Sony Ericsson (see figure 7 sample of modern smartphones). Compared to the early PDAs, they have significantly more processing capacity and larger memory (see table 10 for an demonstration of the evolution). Currently, smartphones exist in parallel with the feature phones and are differentiated from feature phones by the following attributes: larger screen, synchronising abilities, extended keyboard, may have touch screen, more powerful processor, more storage capacity, and full web browser. Furthermore, most smartphones have advanced operating systems as, for example, iOS, Windows Phone, Android and Blackberry OS with open programming interface; permitting third party applications to be installed (Bridges et al. 2010, Visionmobile 2011, Zhang et al. 2010). Although not a distinct set of features, it conveys a notion of what separates a smartphone from a feature phone. Hence, the ability to have third party application installed and the open programming interface are crucial features of smartphones, from a developer perspective.

Figure 7. A set of modern smartphones, which have now replaced the PDA. From the left, Sony Ericsson Experia, RIM Blackberry, Apple iPhone and Nokia Lumina (pictures Pdadb (2011b)). Please note that the devices are not mutually scaled.

Mobile telephony technology quickly developed in parallel with the evolution of handheld technology. The development and launch of mobile telephony started as early as in the 1950s, although it was cumbersome to use due to the lack of roaming ability. In the 80s, Nordisk Mobiltelefoni (NMT) was developed, and Sweden was among the first countries (in collaboration with the other Nordic countries) to develop and launch a commercial mobile telephony service, Automatic roaming ability was a critical factor, making it possible to seamlessly use the mobile phone not only within one country but in all Nordic counties. The original NMT was an analogue circuit switching network with data transfer up to 0.6–1.2 Kbit. NMT was replaced by Global System for Mobile Communication (GSM) technologies (Agar 2005).

Though out of sight in Western Europe, at the time of writing a modernised version of NMT is running, which combines the benefits of low frequencies with CDMA2000 technologies and now offers data transmission speeds of 3.1 Mbps download and 1.8 Mbps upload. Although a marginal phenomenon in Western Europe, it has over 400 million users, primarily in America, Asia, and Eastern Europe (Cdg 2010)

GSM, which is considered the second-generation mobile phone system, uses digital transmission with a transmission speed of 9.6 Kbit. In the 97-release, General Packet Radio Service (GPRS) was introduced, offering packet data switching technology and increasing the transmission rate to 56–114 Kbit. The 99-release, Enhanced Data Rates for GSM Evolution (EDGE) further increased the transmission rate to between 400 Kbit and 1 Mbit (Edge is considered a 3G technology) (Agar 2005, Shim et al. 2006).

In 2001, the 3G network, which was capable of data transmission up to 2 Mbit, was introduced. 3G are usually complemented with High-Speed Packet Access (HSPA) technologies, which increases the transmission rate to 14 Mbit. These high transmission rates make applications such as mobile TV, video on demand, and video conferencing possible. The successor to 3G, which was launched during the time of writing, is the Long Term Evolution (LTE) network, which is capable of data transmission above 100 Mbit (Agar 2005, Shim et al. 2006).

However, most smartphones do not rely solely on the carrier's network; they often have the ability to connect to networks such as Wi-Fi networks with transmission speeds as high as 1 Gbit or other wireless technologies.

Table 10. Progression of technology in terms of capacity and size. Although the values for CPU and memory are averaged (there may exist different versions of the same handset), the sample below displays a significant growth (Pdadb 2011b).

Model	Year	CPU	Memory RAM/ROM / Extension	Weight in grams	H x W x D in mm
Psion Organiser 1	1984	8 bit/ 1 MHz	4 kB/2 kB/NA	225	142 x 78 x 29
HP Jaguar	1991	5.37 MHz	512 kB/1MB/NA	310	159 x 85 x 26
Nokia 9000 Communicator	1996	24 MHz	4 MB/4 MB/NA	397	64 x 173 x 38
RIM 957 Proton	2000	32 bit/ 16–40 MHz	512 kB/5 MB/NA	133	117 x 79 x 18
Nokia 9210c Communicator	2002	32 bit/ 52 MHz	8 MB/32 MB/NA	244	56 x 158 x 27
Motorola E680	2004	32 bit/ 312 MHz	48 MB/32 MB/64 MB	133	109 x 54 x 21
Palm T/X	2005	32 bit/ 312 MHz	32 MB/128 MB/2 GB	149	121 x 78 x 16
Nokia N95	2007	32 bit/332MHz	64 MB/256 MB/32 GB	120	99 x 53 x 21
iPhone 4	2010	32 bit/800MHz	512 MB/32 GB	137	115 x 59 x 9
HTC Desire	2010	32bit/ 1 GHz	576 MB/512 MB/32 GB	135	119 x 60 x 12

Two things are of particular interest here; one is capacity and the other is the form factor. Regarding capacity, there has been a roughly exponential growth in processing capacity and memory capacity, making the computational devices increasingly powerful. Regarding the small form factor, for a two-dimensional form factor (height and width), the area has noticeably decreased by roughly 30%, while the volume has decreased by roughly 500%. An assumption is that the evolutionary pocket size is about 90 cm^2 and is reasonable stable. However, the volume has not been as stable, and time will tell what progress has been made on volume. Of course there exists a middle range of sizes, such as tablets and ultraportable PCs; however, one can question whether these devices are handheld or pocket sized. In this dissertation, the programmable pocketsize device with increasing computing capabilities is the device at hand.

2.1.2 The invasion of handheld computers

The technological evolution has been accompanied by growth in the number of different handheld devices launched on the market. Looking at a timeline from 1990 to 2010, in 1991 only two handheld devices were launched—the HP Jaguar and the Psion Series 3—and since then the number of models launched has steadily increased. In 2010, 462 different devices were launched (see figure 8) (Pdadb 2011b).

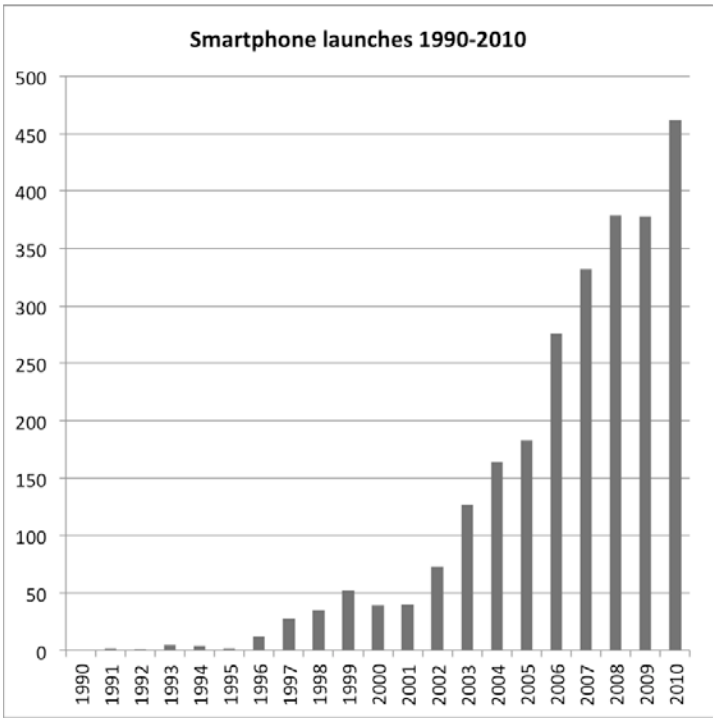

Figure 8. The number of different models of PDA and smartphone launches per year from 1990 to 2010 portrays the invasion of handheld devices on the market, data collected from PDAdb.net (Pdadb 2011b). Please note that feature phones are not represented in this diagram.

The evolution and invasion of handheld devices are the foundation of an expanding technology base which is regarded as one of the most prominent trends in the information system domain today, and views such as *the mobile decade* give an indication of the expectations put on mobile computing, see for example: Stafford and Gillenson (2003), Urbaczewski et al.(2003) and Sorensen (2011). Another indicator of the industry's importance is that the mobile industry has grown to enter the 1 trillion dollar club along with, for example, food, automotive and arms (Visionmobile 2011). This expanding technology base brings opportunities for new applications to be built, for changed workflow for users, and for new user groups to gain from mobile and handheld technologies.

2.2 From the technological platform to workplace users

Now that the technological context has been demonstrated, it is time to discuss aspects of users and uses of handheld computing. This section attempts to interconnect the technology with the circumstances under which the technology is used.

2.2.1 Changes triggered by new technology

The introduction of new technologies may sometimes trigger unexpected changes. In Denmark, a handheld information system supporting homecare staff was implemented in a set of Danish municipals. The homecare staff was equipped with PDAs for work reporting and management of medical records in the field. Prior to the introduction of the computerised handheld information system, the homecare staff had a routine meeting at the home care centre (i.e., their home base) every morning. The purpose of the meeting was to allocate the daily work assignments—a kind of roll call. After the introduction of the new information system, the roll call was cancelled and instead the homecare staff received their assignments at home via the PDA (and wireless connections) and they left their homes to go directly to the patients. As a consequence, the users thought that their work environment had changed, and relations between colleagues were lost (Agger 2010). As a result of this change, the users lost opportunities for informal knowledge transfer and also had reduced accessibility to supporting technologies such as printers, copiers, journal systems etc. (Orr 1996, Perry et al. 2001).

Another example of unexpected changes arose in a Swedish subsidiary for machinery repairs with ambulatory service technicians, where the paper-based service order system was replaced by a computerised system and PDAs. Unlike the Danish homecare staff, the service technicians were already detached from their base and always leaving home to drive directly to work assignments. However, the processes implemented in the computerised service order system generated unanticipated side effects. When reporting on paper, there was the opportunity to make notes in the margin of paper, i.e., technicians could send additional information that was not applicable in the pre-printed text fields back to the clerks working in the office, for example, *I bought a hose at a local gas station – 2 EUR*. When reporting via the computerised handheld information system, reporting exceptions was problematic and cumbersome. Even though the executives considered the system a success, the users considered the system a failure due to the fact that their time spent on reporting increased from roughly twenty minutes per day to one and a half hours per day (Andersson 2008).

These two anecdotes illustrate that there may be changes that are not easily perceived in advance. In line with this dissertation aim, one can question if these hurdles could be avoided via a more comprehensive approach to the design of such systems.

2.2.2 Workforce mobility

Mobility is a key concept in handheld computing, but it can be interpreted in different ways. It may, for example, describe the portability of the application or the mobility of the user.

Regarding the portability of an application, the most common concept is platform independence, i.e., to what extent the application can be used on different devices such as: handhelds, TVs, stereos, and desktop computers. It also describes the ability to be used on different platforms such as: Windows OS, Mac OS, iPhone OS, Android, and Symbian. In addition to this, an application can also be regarded as mobile if it is developed for a mobile device.

Regarding mobility of the user, describing the user and mobility is problematic if the context is not considered. In other words, the mobility is intertwined with the use situation. One often referred conceptualisations of mobility is the Kristoffersen and Ljungberg model of mobility (1998), which includes the concepts *stationary*, *wanderer*, *traveller*, and *visitor* in a model for mobile use of information technologies. *Stationary* describes the traditional desktop user with a stable working environment. *Wandering* relates to the use of information systems in local mobility, for example, a service technician working at an industrial plant. Characteristically, wanderers move within a predefined area, for example, an office building, industry plant, or hospital. *Travelling* refers to the transport between sites, and while travelling, the user may have the ability to do certain tasks such as take a phone call or work with the computer during a train journey or flight. *Visitors* are users who work at different known areas, for example, a professor who teaches at different universities or a doctor working at different health clinics. The visitor can most likely rely on the resources offered at the actual place of work (Kristoffersen and Ljungberg 1998).

It is noteworthy that since 1998 we have witnessed technological advancements in mobile technologies and potential new user groups have surfaced, necessitating an extension of the model by Kristoffersen and Ljungberg (1998). This extension relates to the user who is always out working in the field—a user detached from any home base or predefined area. This is the user portrayed by the healthcare staff in Denmark and the service technicians in Sweden as described in the previous section. Members of this user group are kind of *digital rangers*, always ranging their territory for assignments, a view supported by Dahlberg (2003).

Arguments to extend the model with the *ranger* is two-folded, first because this user is truly and always mobile and second, this user is different from the other user groups because the lack of additional resources and the lack of informal support from colleagues (Dahlberg 2003, Perry et al. 2001) (see table 11).

Table 11. The original model from Kristoffersen and Ljungberg (1998) extended with the user category *ranger* and the physical location *at remote work site. Ranger* implies the solitary user detached from home base and colleagues. *Remote work site* implies the assumed lack of supporting technologies.

Place → User↓	Home based	Around home base	In transit	At remote base	Remote work site
Stationary	X				
Wanderer	X	X			
Traveller	X	X	X		
Visitor	X	X	X	X	
Ranger			X		X

The user category that this study focuses on is the digital ranger, however, findings may be applicable to other user categories.

Regarding types of applications, the focus is on applications for blue-collar users. The applications developed for the digital ranger often manages support processes (registering of performed services for example) and is a sort of peripheral system rather than a core process system as is often the case for white-collar users and knowledge workers.

Examples are the EASY system at BT-Transport for field workers doing maintenance on forklifts, where the EASY-system end users are interconnected to the Movex enterprise resource planning system (Westelius and Valiente 2006), and the SKINFO system at Graninge Timber for supply change management (Valiente 2006a, Valiente 2006b). This user category also include, for example, ambulatory security guards at Morrison Patrolling (Kietzmann 2008) and appointed security guards in Swedish municipals (Andersson and Hedman 2006). These studies identify users that rely on handhelds and handheld information systems as a support to their core processes.

2.3 The lack of comprehensive frameworks supporting designers

The aim of this section is to identify the lack of evaluated and comprehensive frameworks supporting designers of handheld information systems. As will be shown, the research is scattered and usually only include a few accentuated factors.

A considerable number of publications are descriptive and targeted at managers and executives. The main theme in these publications is to identify the potential effects of mobile technologies on business, see for example: Chen and Nath (2004), Zimmerman (1999), Walker and Barnes (2005), or Sigurdson and Ericsson, (2003). As a consequence, they have limited applicability for designers of handheld information systems.

Moving on to more design-oriented approaches, more or less all design guidelines, descriptions, and frameworks manage one or a few important factors, see for examples Turkmen et al. design guidelines on context aware applications (2010); Karampelas et al. work on diversity of devices (2009); Paul and Kundu's work on energy consumption on mobile devices (2010); Benlamri et al. work on security and identification solutions (2010); Wasserman's work on engineering issues (2010); Mitchell et al. (2006) on using mobility as central concept in design for the mobile workforce, or Gong and Tarasewich's design guidelines for managing small form factor, location awareness, off-task, and heterogeneity of technologies (2004).

Ironically, due to the absence of a comprehensive, or exhaustive, framework, it is difficult to prove that the field is scattered. An alternative (and applied) strategy in the absence of comprehensive frameworks is to study other, closely related, frameworks such as research agendas and literature reviews. In these publications, the different aspects of mobility are often portrayed as a backdrop to the actual publication and can act as a description of the scattered field. Below is a set of seminal publications selected via citations and references, and by analysing this set of publications the scattered nature of the field is indicated (see table 12).

Table 12. Publications were the specific properties of handheld computing are discussed. As mentioned earlier, the interchangeable use of the label handheld and mobile remains among these descriptions and frameworks. The most common label is mobile computing, although it actually concerns handheld computing.

Publication	Fundamental challenges in mobile computing (Satyanarayanan 1996); 615 citations according to Google Scholar
Objectives	The paper is in three parts: a characterization of the essence of mobile computing, a brief summary of the research results, and a guided tour of fertile research topics awaiting

	investigation. The paper should be considered as a report from the front by an implementer of mobile information systems to more theoretically-inclined computer scientists.
Results and conclusions	Four constraints of mobile computing are presented, as well as empirical findings from the Coda File System application and a set of research topics involving metrics.
Implications for this dissertation	Four aspects of mobile computing are presented: hardware limitations due to miniaturisation, security risks as been lost, variation in quality of wireless services, and battery power. However, the constraints are presented by the author only as a backdrop to the discussion, without any further elaboration regarding the constraints or their implications for designers.
Publication	Research commentary: The next wave of nomadic computing (Lyytinen and Yoo 2002b); 396 citations according to Google Scholar
Objectives	The authors formulate a research agenda for nomadic information environments from an information systems perspective. A theoretical framework with the dimensions mobility, convergence, and mass scale is applied.
Results and conclusions	In this seminal paper the author presents eight themes and twenty research questions that ought to be addressed. The research agenda is multifaceted and includes design, development, adoption, learning, platform variation, governance, collaboration, team performance etc.
Implications for this dissertation	The discussion is mostly of a general order, without an explicit focus on design, and there are no specific descriptions of the properties of handheld computing. However, aspects involving design as management of platform variation and the large variation in use conditions are presented, identifying that research is needed in the area of design.
Publication	Mobile commerce: framework, applications and networking support (Varshney and Vetter 2002); 338 citations according to Google Scholar
Objectives	In this article the authors examine how new M-commerce applications can be designed and supported by wireless and mobile networks and mobile middleware.
Results and conclusions	Mobile computing is a multidisciplinary field requiring different methods and competences. Different types of applications are discussed, and research questions are put forth involving wireless aspects, location awareness, pricing, business models, and obstacles for successful implementation of mobile applications for mobile commerce.

Implications for this dissertation	Important issues in development are mentioned, such as network quality of service, interoperability, secure transmission, platform proliferation etc. However, the perspective is M-commerce and how to utilise mobile technologies in commercial aspects.
Publication	Mobile communications and mobile services (Siau and Shen 2003); 198 citations according to Google Scholar
Objectives	The authors studies mobile communication technologies and mobile services. Mobile commerce extends current internet sales channels into more immediate and personalised mobile environments. The paper gives an overview of mobile services, investigates the organisational and technological challenges in providing mobile services, and highlights the research issues in mobile services.
Results and conclusions	Mobile services are portrayed as mobility, reachability, localisation, and personalisation. A range of wireless technologies is presented. Different applications are presented from four major areas: B2B, B2C, C2C, and government. Organisational and technical issues related to these applications are discussed.
Implications for this dissertation	In the context of this dissertation, the most important aspects are the organisational and technical issues, including device limitations, incompatible network technologies, different web languages, security concerns, and trust. The proposed research agenda is tightly coupled to these issues.
Publication	Enterprise mobility: concept and examples (Barnes 2003); 45 citations according to Google Scholar
Objectives	The bulk of attention in the literature examining commercial applications of wireless internet computing has so far been on business-to-consumer markets. This paper explores this emerging area of wireless applications in business, focusing specifically on enterprise mobility. It aims to provide a basic background to conceptual ideas of enterprise mobility and a framework for understanding the development of enterprise mobility in organisations.
Results and conclusions	The study is oriented towards the organisational impact of mobile technologies. Five case studies are presented and the findings reveal large variations in outcome. The case studies indicate that the organisations are still in premature phases and that research on enterprise mobility is in its infancy.
Implications for this dissertation	The most important aspect of this paper is the argument that enterprise mobility as a research area is in its infancy. However the description of mobility is rather simplified and in a narrative form, exemplifying what can be done with

	mobile implementations.
Publication	Research areas and challenges for mobile information systems (Krogstie et al. 2004); 59 citations according to Google Scholar
Objectives	Mobile knowledge workers, who need to access and perform transactions and their work on the information systems of their company and on other systems, are becoming more and more common. To accommodate this shift, a new breed of mobile information systems must be developed. This paper highlights some of the research challenges in the field of information systems development. Due to the nature of mobile information systems, physical-level characteristics also pose new constraints on the upper levels, which need to be taken into consideration.
Results and conclusions	The results are oriented towards modelling and user-oriented tasks. Differences between web and mobile information systems are mapped, and different aspects such as temporal, spatial, uncertainty and task are described.
Implications for this dissertation	The paper provides short and general descriptions of mobility as spatial, temporal, personal tasks, and social information contextual aspects. Suggestions related to design, such as security issues, variation in wireless technologies, time dependencies, and place dependencies are mentioned.
Publication	A roadmap for research in mobile business (Fouskas et al. 2005); 31 citations according to Google Scholar
Objectives	There have been numerous individual and largely isolated attempts to define research efforts in M-business; however, there has been relatively little work defining a comprehensive agenda for M-business research. Following this rationale, the paper puts forward a roadmap for M-business research that defines priorities for future research on mobile business in a systematic and holistic fashion.
Results and conclusions	By applying a framework based on the concepts of value, service, technology, and enablers, the authors present a comprehensive research agenda. They also, perhaps more importantly, highlight the necessity to engage in interdisciplinary research that spans all categories in order to achieve an integrated development of M-business (technology-, business-, and policy-oriented at the same time).
Implications for this dissertation	This is one of the very few publications where the proposed framework is evaluated with the help of other informants; however, the focus is on M-commerce and not on design or specific properties of handheld computing. Regarding

	design-oriented aspects, wireless infrastructure, location awareness, and device limitations are briefly mentioned, without suggestions how to manage them. The need for comprehensive approaches is put forward.
Publication	Mobile computing principles: designing and developing mobile applications with UML and XML (B'far 2005); 61 citations according to Google Scholar
Objectives	Written to address technical concerns that mobile developers face regardless of the platform, this book explores the differences between mobile and stationary applications and the architectural and software development concepts needed to build a mobile application.
Results and conclusions	The differences between stationary and handheld computing are discussed, and design propositions to manage the dimensions of mobile information systems are put forward.
Implications for this dissertation	The author has identified the specific properties of handheld computing with the added dimensions of mobile computing. As one of the few publications with this purpose and contribution, this work represents a new departure in the search for the accentuated factors of handheld computing.

Although it is arduous to map the different aspects of the different papers into equivalent categories; there is a lack of comprehensive approaches supporting designers (as shown in table 12). In general, authors mostly put forth a common-sense list of factors without further elaboration. That is, they do not argue why the mentioned factors, or properties, are important. Furthermore, regarding evaluation of frameworks to support designers, I have not yet come across any comprehensive, and evaluated, frameworks; neither analytically nor empirically evaluated frameworks. There exists a knowledge gap in the form of an absence of evaluated and comprehensive frameworks supporting designers of handheld information systems.

One of the few who put forth a framework for designers is B'Far (2005) where a framework of additional dimensions important in the design of mobile information systems is put forth –however not an evaluated framework. It is important that the B'Fars framework is supported with suggestions on how to manage the additional dimensions in order to strengthen the utility for designers. In B'Far's work, the label 'additional' conveys dimensions added to the design and development of handheld information systems, a reasoning comparable with that of *amplified challenges* (Krogstie et al. 2004). B'Far's dimensions have gained recognition by other scholars—for example:

Corradini and Merelli (2005), Goh et al. (2007), Guerrero et al. (2006), Kim and Fox (2010), Mikkonen (2007); Pabllo et al. (2008), Sklyarov et al. (2007) or Zhanget et al. (2009) — and B'Fars's additional dimensions, due to the design aspiration with them, will be the starting point when building the comprehensive framework.

2.4 B'Far's dimensions — starting point for the framework

What, then, are the differences that distinguish handheld computing from desktop computing from a design and development perspective? Which are the specific factors? As mentioned in the previous sections, one representation of factors specific to handheld computing is the additional dimensions of mobility (B'far 2005). These dimensions are focused on the designer/developer, making it a suitable point of departure for study.

B'Far (2005) identifies seven different, additional, dimensions that constitute an expansion in information system design and development as a result of handheld technologies: *active behaviour*, *multimodal and variant user interfaces*, *large variety of platforms*, *limited power supply*, *location awareness*, *wireless connectivity*, and *limited device capabilities* (figure 9).

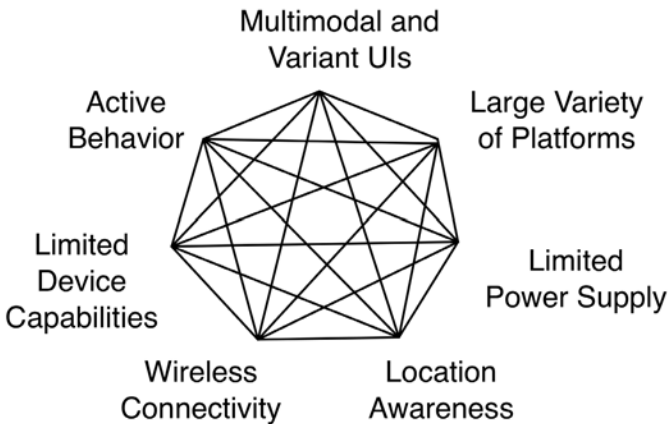

Figure 9. Additional dimensions accentuated by mobility (B'far 2005, p. 9). These dimensions are the starting point in the development of the accentuated factors framework.

Active behaviour denotes desired functionality in an application, something that the designer should strive for. The application should not be passive, that is, waiting on input from the user. Instead it should be active, notifying the user without prior interaction. The argument is that the user is expected to be occupied and focused on tasks other than computing tasks, known as off-computing tasks. One example is Short Message Service (SMS) compared to e-mail. The standard configuration is that an incoming SMS alerts the user without any action from the user (i.e., an active behaviour), whereas usually the user must check the inbox for new e-mail (i.e., passive behaviour).

Multimodal and variant user interfaces expresses differences in input and output options. For the traditional desktop, a keyboard and a mouse are the primary input devices; however, on handheld devices the keyboard is often smaller and more cumbersome to use and the mouse may be missing, while gyro, accelerometer, Global Positioning System (GPS), and touch screen may be available as additional and alternative input options.

Large variety of platforms refers to heterogeneity and diversity due to competing technologies among device manufacturers and numerous stakeholders offering different standards. It is argued that this heterogeneity is larger in the handheld computing domain than in the desktop computing domain.

Limited power supply chiefly means effects of being battery operated. It is argued that consideration must be given to the fact that the handheld device relies on battery power and that the battery can run out of power during a session.

Location awareness denotes the handheld device's ability to know both its present location and previous locations.

Wireless connectivity refers to differences between wired and wireless transmission. Wireless connection is argued to have greater variance in both connectivity and transmission capacity.

Limited device capabilities chiefly refer to effects of miniaturization. The smaller processor is not as powerful as that of a contemporary desktop computer. The memory capacity will most likely be less in a handheld computer compared to the standard memory capacity of a desktop computer. (B'far 2005).

However, there are some issues with consistency in B'Far's framework: it is questionable if four of the seven dimensions are actually dimensions at all. For example, for *limited device capabilities*, *limited* implies a value and the opposite would be unlimited device capabilities, if such a dimension will ever exist. It also implies that there is always an issue with limited device capabilities; however, this must be dependent on the specific application and on the specific case and not a universal law. Similar arguments may be raised against *large variety of platforms* and *limited power supply.* Regarding *large variety of platforms*, there is a large variety of platforms, but there may be situations where the variety can be considered small or even non-existent. For example, in the case where all parts in a system are known, which is usually the case in applications for the mobile workforce where only one device is used and interconnected to only one backend system, ruling out the *large* in variety of platforms. Regarding *wireless connectivity*, wired connectivity may also exist, often in the shape of a docking station. The *active behaviour* dimension is a desired interaction pattern, something that a designer or developer should strive for. However, there may be instances where other interaction patterns are important, such as automated interaction, ruling out *active behaviour* as the predominant interaction pattern. The remaining dimensions—*multimodal and variant user interfaces* and *location awareness*—are non-problematic compared to the aforementioned dimensions.

In the following text each of these seven dimensions are discussed, and questionable labels are elaborated on. The headers in the forthcoming section (2.4.1 - 2.4.7) are labelled according to B'Far's original convention.

Another issue with B'Far's framework is the graphical illustration as a network diagram with nodes and edges (see figure 9). What messages are conveyed by the edges? Are the nodes dependent on all others or do they affect all others? Furthermore, the edges have no directions; do the dimensions influence each other bidirectional; do the dimensions influence each other in the same extent? What messages are conveyed by the placement of the nodes? Are all nodes (dimensions) equally important? The framework is a no-risk framework (Miles and Huberman 1994) and the issues above are not solved or explained by B'Far.

A third issue with B'Far's framework is the concept *dimension*. Typically *dimension* is used on mutually comparable aspects or phenomena, implying equivalent units of measure. Using *dimension* as "*adding a new dimension*" does not rule out the expectation of equivalent units of measure. Thus, to be more rigorous, the concept of *factor* is introduced to replace the concept of *dimension.* In this dissertation, it is argued that *factors* do not imply equivalent units of measure to the same extent as *dimensions*. A *factor* denotes something that can be managed, optimised, dealt with and, as a consequence, affects the outcome of the system built: “a factor is one of the things that affects an event, decision or situation” (Sinclair 1995, p. 595). From a designer’s perspective, things/aspects/dimensions that may influence the outcome are interesting factors.

2.4.1 Active behaviour

“Most of today’s stationary applications have a restriction that can reduce the benefits of a mobile application system enormously: The user of the system must initiate all interactions with the system. We call such systems passive systems because they are in a passive state, waiting for some external signal from the user to tell them to start to do some particular thing. With stationary applications, this typically works well” (B'far 2005, p. 18).

The traditional desktop user usually works for longer periods with the same application, making them on-computing-task (on-task). Being on-task, a passive application causes few problems. However, for those who are off-task, this easily becomes a problem. Since off-task users have other tasks to do away from the computer, it is easy to forget to make downloads (pull) and this is the reason why active operations (push) are preferred (B'far 2005, Tamminen et al. 2004).

Following B’Far argument, passive applications are poor solutions in mobile settings and the user is expected to benefit from active behaviour. This is because the mobile user is not expected to interact with the device between tasks. When the device is out of sight it is also out of mind. The user is also assumed to benefit from short interaction sequences and to be resistant to long boot sequences; therefore, active behaviour is likely to be an appropriate pattern to manage this.

This type of interaction pattern has been studied in empirical settings of the mobile workforce. For example, ecologists working with wildlife protection were studied to investigate how handheld computers and special applications supported them in their work (Pascoe et al. 1998, Pascoe et al. 2000); mobile service technicians in the telecom industry and consultants working with certifications of marine vessels were studied (Kristoffersen and Ljungberg 1998).

The main reason for this consideration is that regarding the mobile workforce, the information systems often manage support processes rather than core processes and the user is often occupied with tasks other than working with their computer, a property usually labelled as off-task (off-computing-tasks).

However, the label *active behaviour* has innate problems; active behaviour is a desired property and a worthwhile design pattern. The mobile user may, or may not, have tasks that will benefit from the interaction pattern of active behaviour.

Hence, *active behaviour* is not a label of a factor that ought to be considered, it is a *solution* regarding a factor. Therefore, active behaviour is relabelled as *task dependencies*, conveying that certain interaction aspects such as off-task may be important to investigate further.

B'Far's suggestion for how to manage task dependencies is obvious: active behaviour.

2.4.2 Multimodal and variants user interfaces

"Stationary users use non-mobile applications while working on a PC or a similar device. The keyboard, mouse, and monitor have proved to be fairly efficient user interfaces for such applications. This is not at all true for mobile applications." (B'Far, 2005, p.15).

This factor is threefold: first are the differences in size compared to desktop computing, such as the screen size and the keyboard layout, second are the additional modes of interaction, such as touch screen, gyro, GPS, and accelerometer, and third is the variety in different user interfaces provided by different device manufacturers (B'far 2005).

The small form factor causes data entry to be more cumbersome than an equivalent task on a desktop computer, as a keyboard may be missing or may have a limited set of keys (Frank 2006). The small form factor also affects output methods in several ways. Even though colour depth and resolution will improve, the size of the screen on a handheld device will remain small due to the portability aspect. The screen size limits what can be displayed and also the usefulness of having several applications open at the same time. On the desktop computer, several applications are usually open at the same time in different windows, while on the handheld device, arrangements like this are problematic, if not impossible. The handheld device interface is more like a deck of cards, where only the top card is readable, and this affects the possibility to run and see multiple applications simultaneously.

Multimodal interfaces mean that there are a greater variety of input and output options, i.e. *variety of user interfaces,* compared to a desktop computer. Gyro, GPS, accelerometer, and touch screen may be available (B'far 2005). In experimental cases, I/O-devices are mounted on the handheld device to increase usability, while in other cases, built-in motion sensors are used to improve usability (Holmquist 2007, Kurniawan 2007).

If multimodal interfaces are what the user encounters using the device, *variety of user interfaces* are something that the designer encounters trying to develop applications for more than one model of devices. There may be differences in screen size or screen resolution within the same product range, and there may be differences between software options within the same range of implemented operating systems.

Summing up these three different aspects, one can argue that two aspects, the small form factor and extended multimodal interface features, belong to the *small form factor*, while the variety of different user interfaces belongs to *large variety of platforms*. The first two aspects are kept in this factor; however, in order to enhance clarity and readability it is renamed to *small form factor-interface.* For the same reasons, clarity, the aspect of variety of user interfaces is moved into *large variety of platforms*.

B'Far's suggestion to manage this is multifarious, using publishing frameworks, WAP, and improved programming patterns such as Model-View-Controller and Presentation-Abstraction-Control patterns (B'far 2005). Studied closer, the proposals converge towards least common denominator strategies, i.e., producing either general code that can be used in different environments or publishing frameworks that do the generalisation-specialisation towards target platform.

2.4.3 Large variety of platforms

The mobile industry is characterised as fast changing and volatile with a large and heterogeneous set of actors and stakeholders. "Because mobile devices are small and there is much less hardware in them than in a PC, they are typically less costly to assemble for a manufacturer. This means that more manufacturers can compete in producing these devices. These cheaper, and typically smaller, devices are sometimes used for special purposes. The sum of these and other similar reasons give rise to proliferation of the types of devices in the marketplace that an application must support" (B'far 2005, p. 18).
These settings creates a complex ecosystem with competing technologies and standards that in turn affects designers aiming to

develop systems that are functional on different platforms or different models from the same device manufacturer, see for example: Basole (2009), Frank (2006) and Holmquist (2007). Furthermore, due to hardware flexing, even developing applications for a specific chipsets can be problematic (Visionmobile 2011). Basole (2009) portrays this complex set of actors as segments in a complex ecosystem and points out fourteen different stakeholders/actors (see figure 10). These aspects remain in this factor but renamed as *platform proliferation*, thus removing *large* in platform variety because it implies a value.

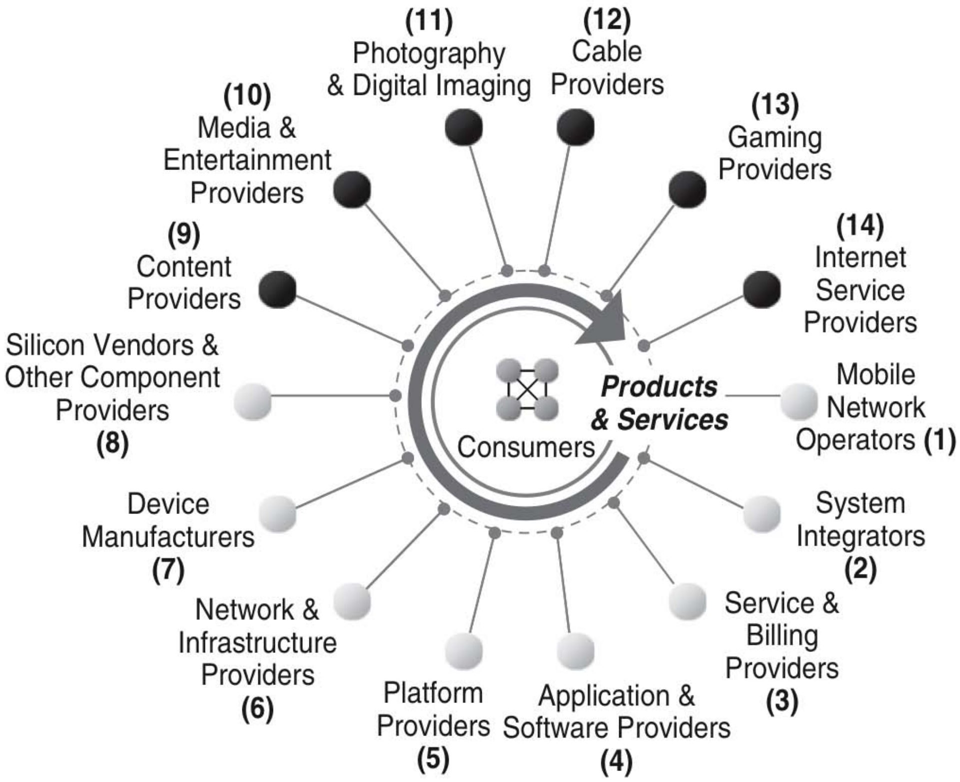

Figure 10. Basole’s illustration of the complex ecosystem of the mobile industry, visualising the multitude of stakeholders (Basole 2009, p 147).

Several suggestions to manage this are put forth; by applying mobile agents’ architecture and the strategy of separation of concerns. Then the device is merely a host for an agent, and the application is an agent that can run on a set of hosts(B'far 2005). Also, the proposal presented regarding multimodal and variant user interfaces is applicable within this factor.

2.4.4 Limited device capabilities and limited power supply

"No one wants to carry around a large device, so most useful mobile devices are small. This physical size limitation imposes boundaries on volatile storage, non-volatile storage, and processor on mobile devices" (B'far 2005, p. 12).

"Wireless is the predominant method of network connectivity for mobile devices, batteries are the primary power source for mobile devices…the desire of using batteries instead of an AC power source combined with the size constraint creates another constraint, namely a limited power supply" (B'far 2005, p. 14).

Two different dimensions that are closely related to each other, as they are both hardware related are put forth. *Limited device capabilities* regards, for example, low processor capacity compared to desktop computing as being a result of small form factor and miniaturization. This makes out a device unable to make equally complex calculations as fast as a traditional desktop computer. Limitations in memory/storage capacity make large applications unsuitable (in the sense that the application require plentiful of storage memory in their installation or data management with large files). Although processing and memory capacity is continuously enhanced, it will always be outperformed by the desktop computer because those devices are also continuously enhanced, becoming faster and with more memory available. The other dimension, *limited power supply*, is a factor that is most relevant for mobile devices, since in reality they require a power source that is independent of the fixed power networks. The processor capacity is related to battery operation; a faster processor most likely requires more power. High-intensity screens and speakers are also related to battery operation; higher intensity leads to increased power consumption (B'far 2005). Newer processor architectures may be power-efficient but most likely there will always be requests for more calculating power for newer architectures (B'far 2005, Sacher and Loudon 2002).

Due to the fact that both dimensions (device capabilities and power supply) are closely related, they are merged into the factor *small form factor: hardware capacities*.

B'Far acknowledges that he cannot propose suggestions regarding this factor; for example concerning limited power supply: "The developer can only affect power use by optimising the operation of the application. This remains a hurdle in writing better, smarter and more user-friendly mobile applications" (B'far 2005, p 790).

This is of course correct; however, if it is out of reach for a designer to solve the problems with battery capacity or power consumption, a discussion in the design phase regarding how to manage a situation where the battery runs out should be fruitful. It is feasible to develop mechanisms that save data and state before running out of battery power, making the device die gracefully and not lose all data.

There are other aspects that ought to be elaborated, such as limited memory capacity and strategies to use cloud services to relieve the device from power and memory consuming activities (Paul and Kundu 2010, Ye et al. 2010).

2.4.5 Location awareness

"A mobile device is not always at the same place: its location is always changing. The changing location of the mobile device and the mobile application presents the designers of the device and the software applications with great difficulties" (B'far 2005, p. 9).

One could argue that location awareness is old news. Location awareness has been used in desktops since the beginning of computers. It comprises regional settings such as time zones, currency and date format etc. The difference with handhelds compared to the desktops is the ability to manage *changing* location, calculating where the device is at a certain moment, something that the desktop computer would not do.

This location calculation can be achieved by different technologies, even without networking ability, for example with Radio Frequency Identification, Near Field Communication, or Global Positioning System. With networking ability, it can be achieved by triangulation, cell information, accessing nodes, and so on. The application can also send its location to other devices, which, for example, can be used to keep track of where colleagues are located.

There has been a considerable amount of work on location-based services, mainly of conceptual type or for marketing, see for example: Junglas (2007), Mennecke and Strader (2001), Rodden et al. (2002), Tilson et al. (2004). However less work on supporting the mobile workforce with applications using location awareness.

I argue that the *location awareness* is better denoted with the label *context awareness*, that is, the surroundings may not only be interesting from a geographically perspective. The physical surroundings are equally important, and context incorporates these surroundings (Schmidt et al. 1999): therefore, the factor *context awareness* is put forward to replace the deprecated location.

Suggestions put forth is the use of location awareness through techniques such as Global Positioning System, Cell base Identification, Time of Arrival, Enhanced Observed Time Difference and Geographic Information System (B'far 2005).

2.4.6 Wireless connectivity

"Whether wired or wireless connectivity is used, mobility means loss of network connectivity reliability" (B'far 2005, p. 11).

The factor *wireless connectivity* represents the unpredictability of quality of service regarding connectivity and transmission capacity. Relying on wireless networks, disconnection is an aspect to consider. Moving between different wireless networks, such as GSM, 3G, WiFi, or Bluetooth, can cause disconnections related to roaming as well as physical hindrance such as road tunnels, buildings, sun flares, and skip zones. This affects both the ability to connect and the transmission capacity, see for example B'far (2005), Dunlop and Brewster (2002), Marcus and Chen (2002). In other words, the designer must deal with unpredictable quality of service when designing applications relying on network resources.

It is understood that even wired connections can vary in quality. A device that is movable between different wired networks creates situations where connectivity can vary. If a wired device is moved to another location the wire is disconnected, loosing connection as a result. When reaching the next wired network, the device must be compliant with that network (B'far 2005).

With the aim of incorporating both wireless and wired connections, the factor is renamed as *varying connectivity*.

B'Far is hesitant regarding how to deal with wireless connectivity, or as he puts it: "Wireless networks will be changing fast. The key for the mobile application developer is to keep up with these changes and to design applications that resists becoming obsolete by these changes." (B'far 2005, p 651).

As a complement to B'Far it is worth considering strategies such as saving data on-deck to manage low quality of service.

2.4.7 B'Far revisited

B'Far's initial dimensions, now rephrased as accentuated factors, have been condensed from seven dimensions to six factors due to the merger of *limited device capabilities* and *limited power supply* into *small form factor: hardware capacities*. Furthermore, Multimodal and variant UIs has been divided—*multimodal UIs* into the *small form factor: interface* and *variant UIs* into *platform proliferation* (see figure 11).

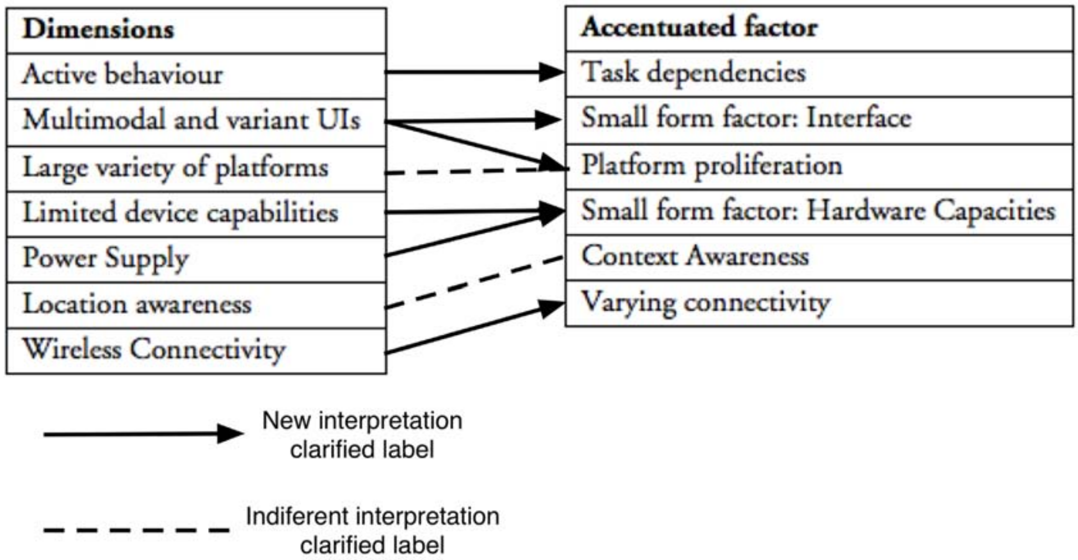

Figure 11. B'Far's seven dimensions (on the left) are transformed to six more consistent factors (on the right). The directional arrows describes a non-reversible change, for example that *Active behaviour* has changed to something different and that *Task dependencies* are not replaceable or equivalent to *Active behaviour*. Furthermore, it can be seen that *Multimodal and variant UIs* are divided into two separate factors, *Small form factor: interface* and *Platform proliferation*.

2.5 Beyond B'Far's dimensions – extending the framework

Additional factors to those expressed by B'Far were identified in a literature search, and these factors are presented in the following sections.

2.5.1 Anywhere

Anywhere can be considered as a trademark of handheld computing and denotes freedom of place, being able to choose wherever to use a computerised service. However, there is ambiguity in the interpretation of anywhere. Does anywhere indicate the mobility of the user, the mobility of an application, or the mobility of a document, see for example: Flynn et al. (2000), Makimoto and Manners (1997), Perry et al. (2001), Zimmerman (1999), and Butz (2004)?

If freedom of place should denote the mobility of the user, then mobility of the device, service, or application is less important because it is context dependent. In some context, the user may be mobile but the application is not, and in others cases it may be the opposite.

However, in a work situation the interpretation of freedom of place can be questioned, and I argue that certain restrictions apply in relation to the mobile workforce that disrupt the notion of anywhere. Most often when a member of the mobile workforce is equipped with a computerised information system, the use is not voluntary but mandatory. That is, the user should use that specific information system and no other, and use it in work-related activities. Contrary to freedom of place, a “just in certain places” restriction may exist. For example, it may be important that an ambulatory doctor is at a specific place (the patient’s location) to do something. To clarify the possible restrictions on anywhere, the alternative label *place dependencies* is put forward and will be used in the forthcoming framework. This does not imply that place restrictions apply in all situations but that place restrictions may apply in specific cases and should be managed properly. If it is important that an application can function in specific places, certain considerations may be needed, for example, if connectivity cannot be guaranteed.

Muhlberger (2004) proposes a solution to problems related to being movable. The proposal regards a specific class of applications intended to run on fixed network computers as well as mobile, potentially disconnected, devices. Those applications are labeled *relocating applications*. The purpose is to support data requirements such that no modification to the application code is needed for data management or disconnection management. The proposal is an application manager, such as a workflow management system, that has a richer awareness of applications through an application-scheme that describes sufficient data requirement information for the execution of application instances.

2.5.2 Anytime

Anytime is almost a sibling to anywhere and can also be considered as a trademark of handheld computing, which denotes freedom of time. It is the ability to access information, services or applications at any time (Makimoto and Manners 1997, Perry et al. 2001).

Expectations to be able to access information whenever it is needed are often considered as a type of one-way reachability in time. An extension is also applicable, describing two-way reachability in time, if someone wants to get in touch with someone else at a certain time (Siau and Shen 2003).

However, a similar ambiguity as for anywhere requires clarification of the interpretation of anytime. Anytime can be portrayed by the ability to check email at any time of the day, regardless of whether it is a working day or a holiday. In contrast to this concept of freedom in time, *when* mobile workforce users need information it may be relatively time-critical information such as the repair status on a machine or a client's purchasing status just before a meeting with the client. I argue that during work time, "just in time" is a more accurate term to characterise the relation between the mobile workforce, mandatory settings, and freedom in time.

To clarify the possible restrictions on anytime, the alternative label *time dependencies* is put forward and will be used in the forthcoming framework. This does not imply that time restrictions apply in all situations but that time restrictions may apply in specific cases and should be managed properly.

2.5.3 Field-use condition

Most work done by members of the mobile workforce, digital rangers, is obviously done in the field, creating a use situation that is usually labelled *field use conditions*. Field-use conditions incorporate physical surroundings such as quiet or noisy environments, sunlight, darkness, heat, or low temperature, all of which influence the usage.

The lack of a predefined workplace is also a part of field use conditions, as mobile workers need be able to adapt to different and diversified workplaces, see for example: Brown and O'Hara (2003), Marcus and Gasperini (2006), Pascoe, Ryan and Morse (1999), Perry et al. (2001), and Schmidt et al. (1999). This factor is labelled *field-use conditions*. It is also argued that supporting technologies, supportive colleagues, onsite work, outbound work, and so on are part of the field use conditions (Cheverst et al. 2000, Van Setten et al. 2004). However, in order to keep the different factors distinct, these circumstances are not incorporated into the factor field use conditions but are managed in the forthcoming factor, supporting technologies.

2.5.4 Security issues

Security issues, such as masking, listening, browsing, and distortion, accompany all communication and communication via wireless networks increases these risks. When the wireless environment is stable and predefined, as within an office building, it is seldom a problem to set reasonable levels of security. However, when the user is mobile and roams different networks, the security levels may vary and may even be unknown (Ghosh and Swaminatha 2001, Nikita et al. 2001).

Another security issue is the small form factor of the device and the device's omnipresence. That is, the small size of the handheld device allows it to be carried around to a greater extent than, for example, a desktop computer. This frequent use increases the risk of it being stolen or lost and, which could result in loss of important information. If critical information is stored in the handheld device, it is a security issue that must be managed (Elliott and Phillips 2004, Ravi et al. 2002).

These two security issues—communication threats and the increased risk of the device being lost—are merged in the factor *Security issues*. B'Far presents a rich description of security threats on a technical level based on the Open Systems Interconnection (OSI) model, however suggestions on how to manage these threats are missing.

One proposal to solve security issues is the five-layer 'onion ring' framework. It is used for analysis of mobile commerce security requirements and for improving system security performance. With a quantifiable approach based on weighted scores applied to either a spider diagram or a decision solution matrix, the security level can be measured and evaluated in addition to the technical discussions on the framework's architecture (Wei et al. 2006).

Another proposal is the strategy of implementing strong WLAN security for companies using a visual security assessment framework for wireless information assurance: Corporate WLAN Security Assessment Framework (Choi et al. 2006).

2.5.5 Supporting technologies

Compared to desktop computer users, the mobile workforce's accessibility to additional or supporting technologies is usually limited. Important printouts may not be easily accessed or displayed through a handheld device with small screen. File management, servers, fax machines, written manuals, written ledgers, blueprints, or other support systems may not be present in the same way as in an office, see for example: Brown and Kenton O'hara (2003), Perry et al. (2001), Zheng and Yuan (2007).

One response to this is the "Swiss army knife" approach, constructing a multipurpose device that can do almost everything (Marcus and Chen 2002, Shim et al. 2007). However, this approach is questionable because a device that is able to do everything may not be good at anything (Schilit and Sengupta 2004).

Multifarious aspects involving supporting technologies and additional technologies are combined in the factor labelled *supporting technologies*.

2.6 A tentative comprehensive framework

Summing up the factors yields a tentative framework of eleven factors that should be managed in various extents in the design phase of a handheld information system for the mobile workforce. Table 13 presents a summary, in alphabetic order, of the factors.

Table 13. The tentative set of accentuated factors of handheld computing, derived from literature.

Factor	Description
Context awareness	The device's ability to recognise the location or context, both in the present and in advance
Field-use conditions	Aspects such as noisy surroundings, darkness, sunlight, rain, cold or hot surroundings, and the lack of desktop
Place dependencies	Replaces anywhere and includes "just in place" in the concept
Platform proliferation	Describes the large variation in stakeholders and the low degree of standardisations as a consequence
Security risks	Factors such as threats to wireless communication and the ever presence of the device, exposing it to theft

Small form factor: Hardware capacities	Battery capacities, memory capacities, processor capacities etc., which may toned to be managed depending on the use situation
Small form factor: Interface	Concerns the small screen, the small keyboard (physical or virtual on the screen), and multimodal interfaces such as audio and motion
Supporting technologies	Being outbound usually reduces the possibilities to use fax machines, photocopiers, and file servers, etc.
Task dependencies	Sometimes labelled off-task versus on-task. The mobile user is usually off-computing-tasks (off-task) and, as a natural consequence, focused on tasks other than information handling.
Time dependencies	Replaces anytime, including "just in time" in the concept
Varying connectivity	The wireless connection may be unreliable and varying to a larger degree than the fixed equivalent.

It is a deliberate choice not to illustrate the factors graphically as B'Far (2005), see figure 9 in section 2.5, because it can impose relations between factors and confuse the reader (see section 3.4.1 for reflections regarding this).

Furthermore, no claim is made that this is an exhaustive or comprehensive framework; it is a tentative framework built on available research published in books and peer reviewed conferences papers and peer reviewed journals articles.

2.7 Knowledge gaps in relation to the tentative framework

The aim of this section is to identify to what extent the different factors in the tentative framework have been investigated in prior, available, research. Section 2.7 is entirely based on the findings in paper 1 (Andersson 2010).

Identifying factors less researched guides into areas where the utility of that research would be positive. Hence, the marginal utility of further studies on well-researched factors would be low.

The applied framework in the paper is based on: *the tentative framework*, *the mobile workforce*, and *design-oriented approaches*.

Regarding *the tentative framework*, this refers to publications managing one or more factors belonging to the accentuated factors framework of handheld computing. The findings indicate that the most researched factors were those that can be considered as obvious for handheld computing: *the ability to calculate its location (context awareness)*, *the pocket size format with limitations in input and output*, *wireless connectivity*, *hardware limitations,* and *security issues.* If the obvious properties of handheld computing are well illuminated, the more subtle properties lack illumination. In total, *supporting technologies*, *time dependencies*, *task dependencies* and *field-use conditions* account for only 7.0% of all publications (see table 14). Interestingly, these latter factors are arguably important for the mobile workforce.

Concerning *the mobile workforce*, this refers to publications studying organisational settings relevant to the mobile workforce (business-to-employee etc.). The distribution between organisational settings reveals that research on the mobile workforce represents 14.7% of the selected articles (see table 15).

Finally, *design-oriented approaches* concerns research with a prescriptive approach. For a detailed account of the importance of design-oriented approaches, see section 3.2. The distribution of design-oriented approaches indicates a preference for such approaches, which account for 52.9% of the publications compared to descriptive approaches, which account for 47.1%.

Taken together, the literature review supports further studies on factors such as *supporting technologies*, *time dependencies*, *task dependencies* and *field-use conditions*. Furthermore, studies of the mobile workforce are still valuable, both in relation to the knowledge gaps identified in paper 1 and in relation to the expectations on handheld technologies for the mobile workforce as described in section 1. Based on these results it is feasible to rule out further research on the *small form factor interface*, *location awareness, small form factor hardware* and similar factors.

Table 14. Distribution of accentuated factors in the examined publications, based on the literature review in paper 1. In the paper, twelve factors are studied because an additional factor, *Application dependencies*, was identified in empirical data and probed in the paper. This factor should be ignored in this phase of the reading; however, it will resurface further on.

Factor	Number	Percentage
Context awareness, descriptive	13	12.7%
Context awareness, prescriptive	13	12.7%
Small form factor: Interface, descriptive	14	13.7%
Small form factor: Interface, prescriptive	8	7.8%
Varying connectivity, descriptive	2	2.0%
Varying connectivity, prescriptive	12	11.8%
Small form factor: Hardware capacities, descriptive	1	1.0%
Small form factor: Hardware capacities, prescriptive	9	8.8%
Security, descriptive	4	3.9%
Security, prescriptive	5	4.9%
Place dependencies, descriptive	7	6.9%
Place dependencies, prescriptive	0	0.0%
Platform proliferation, descriptive	3	2.9%
Platform proliferation, prescriptive	3	2.9%
Field-use conditions, descriptive	1	1.0%
Field-use conditions, prescriptive	1	1.0%
Task dependencies, descriptive	0	0.0%
Task dependencies, prescriptive	2	2.0%
Time dependencies, descriptive	2	2.0%
Time dependencies, prescriptive	0	0.0%
Application dependencies, descriptive	1	1.0%
Application dependencies, prescriptive	0	0.0%
Supporting technologies, descriptive	0	0.0%
Supporting technologies, prescriptive	1	1.0%
Total	*102*	*100%*

Table 15. Distribution of organisational settings factors in the examined publications, based on the literature review in paper 1.

Organisational settings	Number of publications	Percentage
B2E or B2B	15	14.7%
B2C or C2C	37	36.3%
Neutral (Technical or neutral)	50	49.0%
Total	*102*	*100%*

2.8 Contribution in chapter 2

The aim of this dissertation is to address a lack of a comprehensive approach by developing a comprehensive framework and a toolkit derived from the comprehensive framework.

In the beginning of this chapter the lack of a comprehensive frameworks are identified, hence reinforcing the argued lack of comprehensive framework put forth in chapter 1.

However, the primary contribution in this chapter is the tentative comprehensive framework of accentuated factors based on available research. A tentative framework, that will act as foundation for the forthcoming work. In conjunction to this tentative framework: areas where a pursuit for more knowledge is valuable are identified with a literature review. Hence, guiding the forthcoming empirical investigations.

Furthermore, in order to contextualise the settings and convey where the framework is applicable, the technology in shape of handheld devices and the digital ranger as the user at hand is put forth.

Taken together, the overall contribution in this chapter is the reader now should better apprehend the motive for the dissertation aim, the settings for the research and the properties of handheld computing.

3 Research approach and methods

The aim of this section is to describe the philosophically underpinnings and methods used to fulfil the dissertation's aim. Being a cumulative dissertation with appended papers, a considerable portion of the method is already presented and discussed in papers. Accordingly, this section mainly discusses the issues not mentioned in the papers and a more detailed presentation on case organisations, compared to that in the paper, is made in this section.

However, this chapter starts with a presentation of my pre-knowledge when admitted as a PhD student, as suggested by Järvinen (2001). A pre-knowledge that has influenced the choice of topic, approach and desired outcome of this study.

3.1 Pre-knowledge when admitted to PhD studies

When I was offered admission to the PhD program at the Department of Informatics I already had some experience of design and development of systems related to handheld information systems. This knowledge guided me if not to a research question: at least into an area of investigation—the specific nature of mobile computing from a designers' perspective.

At the beginning of 2005, I was contacted by the CEO of 21st Century Mobile Solutions AB and offered a part time assignment of chief technology officer, supervising the development of a communication platform. The platform was considered as a bridge between the island of computers and island of mobile phones, offering a solution to the problems of interconnecting these two islands. My experience was in computers, primarily in web systems and database design. Notably, in 2005 neither the iPhone nor Android smartphones had reached the market with their software development kits (SDKs) for developers. Designing and developing an application pushing trivial information from a backbone system to mobile phones was problematic in 2005.

At 21st Century Mobile Solutions, developers with varying competence were recruited, from newly graded system developers to consultants with long experience of in-house development at Telia (one of the mobile operators in Sweden).

When developing the platform, it was a rather straightforward job to design and develop the desktop applications and the server-to-desktop connections. However, when connecting operators and connecting mobile phones we encountered unexpected problems. These problems were mainly due to the lack of standards, platform variation and continuous updates from both mobile operators and mobile device manufacturers. These findings resulted in the paper *Issues in the Development of a Mobile based Communication Platform for the Swedish Police Force and Appointed Security Guards* (Andersson and Hedman 2006), which was published and presented prior to my admission to PhD studies.

When I was admitted as a PhD candidate, my interest was in the design of mobile information systems in some not yet clarified guise. After some time, this interest was distilled down to investigation of the specific nature of handheld computing and how it could affect design and development of handheld information systems.

During my time at 21st Century Mobile the development team and I often discussed problems in translating research on information system design into applicable knowledge for practitioners—a discussion probably originating from the fact that I was a university teacher and all employees had university degrees.

As a direct consequence of these discussions, combined with my own experience of problems regarding the design of handheld information systems, I set my agenda to put forth a contribution that was applicable in practice. This agenda was finally expressed as a design science approach due to the articulate utility-perspective. That is, design science is assumed to yield research that are more relevant for practice than more traditionally approaches which risk being too reductionist, too broad or too trivial to be of any practical relevance (Van Aken 2004).

3.2 Design science as a research approach

As mentioned in the previous section, the research presented in this dissertation is underpinned by a design science approach due to the utility aspiration for the outcome of my research. Although it has been used in research for a long time (Simon 1969), design science is argued as being relatively new in the information system discipline (Hevner et al. 2004).

In recent decades, interest has increased and voices have been raised regarding the relation between design science and natural or social sciences and questioning if the major perspectives of natural or social sciences are useful when dealing with design as a scientific discipline, see for example: Archer (1979), Gregg et al. (2001), Kuechler and Vaishnavi (2008), and Nadler (1980). Hence, this section begins with an account of design science as an alternative to more traditional approaches, a section that has a specific raison d'être due to the current debate on this topic, see for example: Agarwal and Lucas (2005), Lyytinen and King (2006) and Weber (2003).

In the seminal work *The Science of the Artificial*, Simon (1969) argues that there is a need for a specific science for design. The cornerstone of design science is that it is constructive, while natural or social science is analytical. This resulting in design science with a "how to" or "how things ought to be" perspective; instead of the "how things are" perspective in natural and social sciences (Simon 1969). It is the conception of realisation of new things; it deals with the planning, invention, and construction of artefacts. Its language is modelling and it has its own specific perception on things to know, ways of knowing them, and ways of finding out about them (Cross 1982), or as Archer, Baynes and Langdon (1975) put it, it is the art of planning, inventing, making, and doing, and this is the root of the discussion on the appropriateness of applying perspectives from natural or social sciences to design-related research.

According to Simon (1969), design science should borrow concepts from both natural and social sciences to ensure rigour and scientific credibility. But here emerges a paradox: if design research is different from natural and social sciences, why strive so hard to impose the values of natural and social sciences on design science? This view on design as a science is questioned, and arguments are raised that design as a research topic should not try to strive for the ideals of natural or social sciences (Cross et al. 1981). The alleged need to impose values from natural and social sciences resurfaces in the discussion on information system design research, as will be shown in the following section.

Simon's view on design science has also been questioned for being positivistic, rational, and only dealing with tame problems. For example, Schön (1983) argues that design is a complex process comparable with art, and with a departure from constructivism instead of positivism the focus should be on design-thinking research, the reflective practitioner, and wicked problems—a perspective that has gained considerable support, arguing that design is a discipline more than a science, see for example: Cross (2004), Cross et al. (1991), Goldschmidt and Porter (2004) and Lawson (1980). One can argue that Simon and his proponents are more focused on the artefact, the product of design, and Schön and his proponents are more focused on the process of design. However, both the product and the process are part of design, and one can choose to focus on the product, or the process, or to encompass both product and process when studying design (Cross 1982, Mckay and Marshall 2007, Walls et al. 2004). If studying the process, the focus is usually inwards to the designer, based on how the designer thinks and acts and leaving out parts of the properties of the material. On the other hand, when studying the products, the properties of the material are foremost and the designer's thoughts and internal processes are downplayed. However, this does not rule out the reflective practitioner as a concept. The reflective practitioner also needs information on the material culture to be able to reflect on actions. In this dissertation, the artefact, its properties in the shape of factors, and how to manage those factors are in focus, while the designer's thoughts, mental processes, and so on are downplayed. In conjunction with this, valuable insights can be gained from Cross (1982). He argues that in design science one can study the *actual product* (i.e., the application), or *the process of developing it*, or *the intertwining of the product and the development process*. In this dissertation, it is argued that there is a change stemming from technological development creating a material culture worthy of further investigation, and because of this the *actual product* is under investigation.

3.2.1 Design science in Information Systems

Design science is applicable in most areas of the artificial, for example, architecture, engineering, or information systems. Each of these areas has its own problem domains; with specific materials and outcomes; and methods and means for verification. What is the material in information system design science? In other words, what are the phenomena of interest for information system design science activities?

The following section will narrow down the scope to design science within information system research.

There have emerged two major strands in information system research: information systems design theory (Walls et al. 2004, Walls et al. 1992) and design science research (Hevner et al. 2004), and the common agreement is that they both focus on the IT artefact and downplay the socio-technical aspects. A third school of thought is suggested, which encompasses the human as an important part of the information system field (Mckay and Marshall 2005). A school of thoughts in line with the unit of analysis in this study and the perspective on information systems design applied in this study.

In this dissertation, the following characterisation of artefact is applied: they may be *instantiations*, *abstract artefacts*, or *human understanding of artefacts*. Instantiations are artefacts that have a physical existence in the real world. It may be an application such as a web shop or a specific development process applied in a system development project. Abstract artefacts are by definition not present within a physical representation, instead they must be conveyed by other means. It may be by words, models, diagrams, design principles, or likewise describing something that may be instantiated. Human understanding of artefacts conceptualizes and describes artefacts in abstract and general terms. There is a set of relations between these categories that denotes how humans both create and use instantiations and abstract artefacts (see figure 12). Furthermore, design principles can be derived from observations and interaction with existing artefacts (Gregor and Jones 2007).

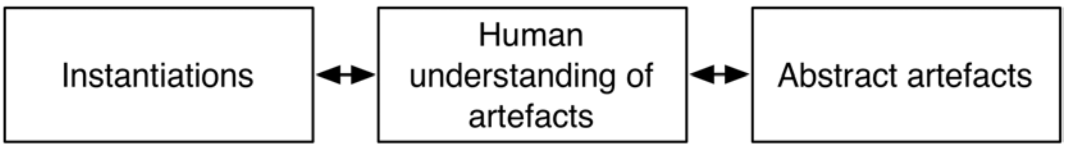

Figure 12. The possible outcomes of design research and their relations according to Gregor and Jones (2007). Instantiations are real world artefacts as an implemented service order system or an iPhone App. Abstract artefacts are for example models, process descriptions and theories. Human understanding of artefacts and the relation to the other outcomes shows that humans may study an instantiation and understand the artefact, also that humans can apply abstract artefacts in order to build instances. Figure adopted from Gergor and Jones (2007,p 321)

Here I find it necessary to state that I fully agree with Gregor (2009), Gregor and Jones (2007), and Venable (2006) that design principles can be derived from observations of, and interactions with, artefacts. However, several researchers have argued that we should be informed mainly by references or kernel theories from psychology, mathematics, and so on (Hevner et al. 2004, Simon 1969, Walls et al. 1992). I argue that if we do not appreciate observations and interactions, or other design research, a lot of valuable information will be lost. For example, findings regarding field use conditions, which are typical for the mobile workforce, have been found in observations, without the application of natural or social scientific theories (Kristoffersen and Ljungberg 1999, Pascoe et al. 2000). If the knowledge regarding field use conditions is discriminated against or not considered as appropriate due to the lack of natural or social scientific theories informing this condition, or "paying tribute" to kernel theories (informing the kernel theories), design science will be nothing more than a laboratory for natural or social sciences, a standpoint also supported by Weber (2003).

3.2.2 Reporting design science outcome

The main recipient of information system design science is the information systems practitioner community (Carlsson et al. 2010). Design science efforts must not only produce an artefact, they must also produce knowledge that practitioners can utilise, and there exist different suggestions on how to formulate this knowledge.

One approach is to formulate design propositions, the rationale being the possibilities to further enhance them into design theories. The term "design proposition" is used in management research and follows the logic of a technological rule. In the field of information system, it may be more appropriate to use the term design proposition instead of technological rule, since the latter term may suggest a technical, rather mechanistic approach. A design proposition can be expressed as: if you want to achieve X in situation Y, then something like action Z will help. The contextual dependency and the condition that design propositions must be interpreted in a specific setting also indicate that design proposition is a more suitable label than technological rule (Van Aken 2005).

In this dissertation, a set of design propositions is presented as reports on design research. These design propositions will be structured according to Gregor and Jones's (2007) framework on information system design science outcomes. Their framework consists of six core components: *purpose and scope*, *constructs*, *principles of form and function*, *artefact mutability*, *testable propositions*, and *justificatory knowledge*. These basic components are extended by the additional components *principles of implementation* and *expository instantiations*. *Purpose and scope* "says what the system is for." To understand an artefact it is necessary to understand the context and the circumstances it operates within. To be a valid description of *purpose and scope*, the context and reason for the artefact's existence must be clarified. *Constructs* concern representations of the central entities in the theory; they can be assembled from words, diagrams, or mathematical symbols. *Principles of form and function* describe how the artefact is constructed and are a blueprint of the artefact. *Artefact mutability* portrays the evolutionary properties of information system artefacts, that it is difficult to define a design due to this ever-changing material. An ambition should be to consider these evolutionary properties in a design theory. *Testable propositions* are statements of causality, either algorithmic proposition that can be tested or heuristic propositions with a form as "a likely outcome." These propositions are difficult to test due to the nature of information systems, but there should be an on-going effort to achieve such propositions. *Justificatory knowledge* concerns the explanatory knowledge that links goals and materials. *Principles of implementation* are the components by which the design is communicated. *Expository instantiation* is the physical implementation of the artefact (method or application). If there only exists an expository instantiation without an accompanying theory of design there are no contributions to the body of knowledge in design science research (see table 16) (Gregor and Jones 2007).

Table 16. The structural components of theories in IS research, adopted from Gregor and Jones (2007).

Theory Components	Description
Core Components	
Purpose and scope	What the system is for and in what circumstances it should be used; a set of meta-requirements or goals that specifies the type of artefact to which the theory applies and defines the scope or boundaries of the theory

Constructs	Denotes the phenomena of interest in the theory; the concepts and entities that are used in or by the theory
Principles of form and function	The model or the architecture describing an artefact, being either a product or method; a "blueprint" or an outline of the form of the proposed artefact
Artefact mutability	The changes in state of the artefact anticipated by the theory, that is, what degree of artefact change is encompassed by the theory? The IS artefact is ever-changing, so how does the proposed theory manage the mutability?
Testable propositions	The artefact may provide a testable proposal or hypothesis such as "if you want to achieve X in situation Y, then something like action Z will help."
Justificatory knowledge	The underlying knowledge or theory from natural, social, or design science that gives a basis and explanation for the design (kernel theories); it explains why an artefact is constructed as it is and why it works
Additional Components	
Principles of implementation	A description of processes for implementing the artefact in a specific context; how to use the proposed artefact
Expository instantiations	A physical implementation of the artefact that can assist in representing the theory both as an expository device and for the purpose of testing

3.3 The applied research model

Having explained design science and its constituents and clarified the expected outcome, it is now time for a presentation of the research model used in this study.

Based on the previous section, the research model from Carlsson et al. (2010) is adopted. This model is developed to manage socio-technical information system design and is composed of four research activities: *identify problem situation and desired outcomes*; *review extant theories, knowledge, and data*; *propose/refine design theory and knowledge*; and *test design theory and knowledge* (see figure 13).

Identify problem situation and desired outcomes: One important aim in design science is to create theories that can be used by practitioners in their work. For this reason, the problematic situations of interest are those of a practical rather than theoretical nature. For the same reason, the outcome will be theories that are prescriptive and goal oriented.

Review extant theories, knowledge, and data: Design theories should be grounded in prior theories and knowledge and further enhanced and tested against existing theories. It is important that knowledge is considered as a valid basis for design theory, i.e., knowledge that has not yet become theory is useful for building theories. This allows practitioners' knowledge and rich descriptions to become foundations for design theories that open up the widest possible range of resources. As such, rich descriptions of field workers in Africa (Pascoe et al. 1998) could be the basis for design theory.

Propose/refine design theory and knowledge: When a design theory, i.e., a design proposition, is proposed, it is important to offer a contextual description to help the reader understand the theory and to help supporting practitioners in translating the theory to specific contexts and situations. The socio-technical nature of IS makes propositions contextually dependent. They must be interpreted in context, and this is impossible if the propositions are not combined with rich descriptions. Design proposals are heuristics, which means that they are not law-bound but should be seen as suggestions that "should work", closely related to technological rules (Van Aken 2005).

Test design theory and knowledge: When a design theory is formulated it should be tested, and a technique is to examine its generalisability by changing settings and context to see if it still works. By improving the proposition with several iterations, saturation will be reached eventually.

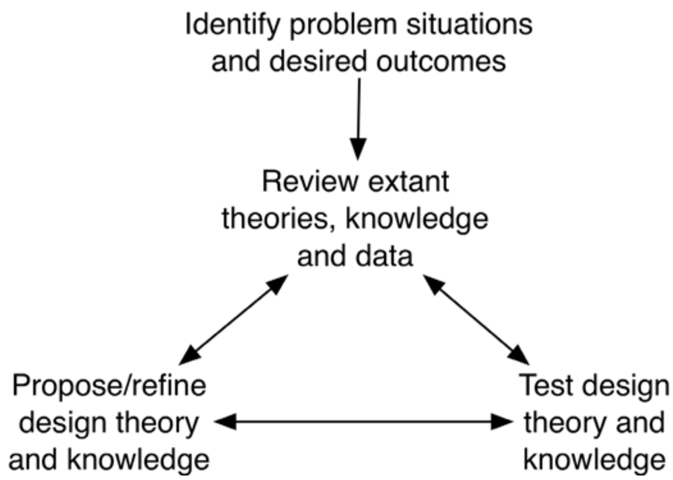

Figure 13. The research model adopted from Carlsson et al. (2010, p 114). The bidirectional edges describe the iterative process of developing design theories.

The iterative nature of the proposed model is important; there is no explicit sequential process or logical path to follow, rather the activities *Identify problem situation and desired outcomes* and *Review extant theories, knowledge, and data*. Although the presentation below in four different sections below may imply a sequential order, that would be a misinterpretation of the model at hand. In fact, the model corresponds to the iterative, and intertwined, nature of the work accomplished in this study.

However, there is an inherent problem in describing an iterative process such as the research process: the devil is in the details. If describing all iterations, the descriptions below would be very complex and impossible to interpret. For example, the labelling and descriptions regarding the accentuated factors have been discussed by peers in several seminars at the Swedish Research School of Management and Information Technology; at research seminars at the Department of Informatics; with peers at research conferences, and thereby an iterative and evolutionary refinement of the concepts has been performed.

In its place, a simplified description is put forth describing the major steps in the cumulative research process. In fact, the main structure of the cover is a simplification in order to present the research more linearly in order to increase readability, as suggested by Suddaby (2006).

3.3.1 Identify problem situation and desired outcomes

The identified problem in this dissertation is the lack of comprehensive frameworks and toolkits supporting designers of handheld information systems. It corresponds with the research model that suggests that problems of a practical nature are of particular interest. The desired outcome is in the shape of a framework, design propositions, and a toolkit, i.e., the outcome will be prescriptive and goal oriented (see table 17).

Table 17. The activity performed in "Identify problem situation and desired outcomes"

Activity
Identify lack of comprehensive frameworks and toolkit supporting designers, normative outcome. Section 1.1–1.3

3.3.2 Review extant theories, knowledge, and data

Following upon the first activity in the research model, the next activity is the use of previous research and empirical data. It includes previously published research, any prior knowledge, pre-existing data, and data created in the research process (see table 18).

Table 18. The activities performed in "Review extant theories, knowledge, and data"

Activity
Develop a tentative framework of accentuated factors from previous literature. See section 3.4 for a description of the applied method.
Review areas for further study in conjunction with the list of accentuated factors. See section 3.4.2 for a description of the applied method.
Carry out three case studies. See section 3.6 for a description of the case study design.
Derive new factors from case findings. See section 3.6 for a description of the applied method.
Analyse experts' opinions on the tentative framework. See section 3.6.3 for a description of the applied method.
Derive design considerations from case findings. See section 3.6 for a description of the applied method.
Identify dependencies between accentuated factors. See section 3.6 for a description of the applied method.
Design a tentative version of the Toolkit. See section 3.6.5 for a description of the applied method.
Analyse the evaluation of the Toolkit. See section 3.6.5 for a description of the applied method.

3.3.3 Propose/refine design theory and knowledge

When extant theories and data are analysed, design suggestions in the form of toolkit, framework, and design propositions managing specific factors are put forth (see table 19).

Table 19. The artefacts put forth in "Propose/refine design theory and knowledge"

Activity
Tentative framework put forth. See section 2.6.
Comprehensive framework put forth. See section 4.1.1–4.1.5.

Relations between factors put forth. See section 4.1.5.
Least Common Denominator design proposal. See section 4.3.1.
Flexible Forms design proposal. See section 4.3.2.
Tune-In design proposal. See section 4.3.3.
Defensive Design design proposal. See section 4.3.4.
First version of Toolkit proposed to students. See appendix 7.8 on first versions of Toolkit.
Evaluated Toolkit proposed. See section 4.2 for a description.

3.3.4 Test design theory and knowledge

The formulated design proposal, theories, or models are evaluated via implemented solutions, experts, users, or scholars (see table 20).

Table 20. The artefacts put forth in "Test design theory and knowledge"

Activity
Tentative framework evaluated by experienced practitioners. See section 3.6.3 regarding method.
Comprehensive framework tested on peers via review and conference presentation. See paper 2.
Relations between factors. See paper 3.
Least common denominator implemented and tested on peers via review and conference presentation. See paper 4.
Flexible forms evaluated by users and tested on peers via review and conference presentation. See paper 5.
Tune-In implemented and tested on peers via review and conference presentation. See paper 6.
Defensive Design implemented and tested on peers via review and conference presentation. See paper 7.
Toolkit method evaluated by students. See section 3.6.5 regarding method.

3.4 Review of extant theories

In this section, the activities described are the development of the tentative framework; the first literature review on knowledge gaps in relation to the tentative framework (paper 1); and a literature review in relation to the evaluated and comprehensive framework (paper 8). Regarding paper 1 and paper 8, most of the method is already described in the papers and here only a developed discussion on analysis is presented.

3.4.1 Development of the tentative framework

As presented in chapter 2, the accentuated factors framework begins with the additional dimensions of mobility by B'Far (2005). In order to "discover important variables relevant to the topic" (Hart 1998, p 27) a systematic literature review were carried out and by this extending the original framework.

In order to find publications managing factors relevant for handheld information system design, books, publications in peer-reviewed journals and peer-reviewed conference proceedings were searched and analysed.

Two main strategies were applied in this search, on one hand, a snowball selection based on identified concepts, and on the other hand, a citation search strategy.

The snowball selection strategy was to apply search phrases based on B'Far's initial dimensions and thereby new publications were found. If these publications contained new concepts (a concept could be "limited power supply" or "field use conditions") or variations on known concepts (variations on a concept could be "platform proliferation", "platform variation", "standardisation", or "heterogeneity"), these concepts became the basis for new search phrases.

However, snowball selection has both strengths and shortcomings. The method is valuable when it is difficult do develop a complete framework in advance. That is, if not all concepts are known in advance as in this case. A shortcoming is that it is very difficult to know when saturation is reached, when the new framework is complete (Dahmström 2011).

To complement the snowball selection the citation strategy was applied. The citation strategy was to check reference lists in the publications to find out what previous research the publications were based on. In this way, a backtracking to original sources was made, during which new concepts, variants on known concepts, and seminal articles were found. By a process of "forward tracking", publications referring to "seminal" publications were found. This strategy was an attempt to ensure that both early and important work and up-to-date material were represented in the framework as suggested by Hart (1998) and by Webster and Watson (2002).

The databases used in the development of the tentative framework were library databases such as LOVISA and ELIN and databases such as IEEE, ACM, JSTOR, AIS, and Google Scholar.

In order to systematise the analysis of factors gathered, a model of common entities in system development was constructed. Often-used entities in system development are *user*, *application*, and *device* (i.e., the platform), see for example: Bansler (1990), Fitzgerald et al. (2002), Mathiassen and Franzén (2001). To capture the environmental settings as being part of the mobile workforce, the entity *organisational settings* was added (see figure 14).

The development towards a tentative framework has, however, been an iterative process with varying representations, concepts, and labels. Early versions of the tentative framework have been exposed to peers, both at seminars at the Swedish Research School of Management and Information Technology and at the Department of Informatics, Lund University, via peer-reviewed conference papers (Andersson and Henningsson 2010a) and peer-reviewed book chapters (Andersson and Henningsson 2010b), and by this means an iterative extension and enhancement of the tentative framework have occurred.

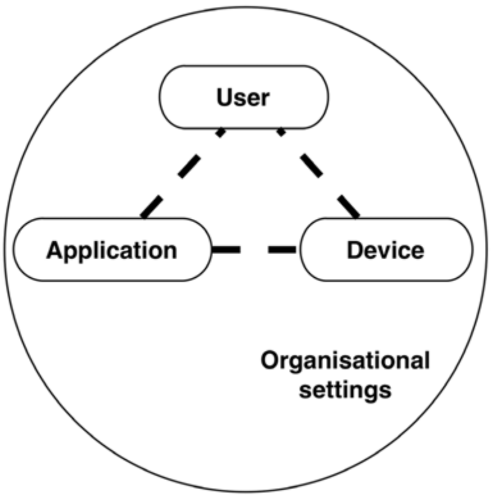

Figure 14. An early version of the framework applied in the analysis of accentuated factors, presented in Andersson and Henningsson (2010a). The connection between the entities application, user and device imply dependencies between them and that properties may in some circumstance overlap. The entity organisational setting is overarching and may affect all the other entities.

After some work, a problem with the framework illustrated in figure 14 was discovered. Aspects of connectivity were problematic to place in the applied framework. Was poor connectivity a problem manageable from a device perspective or an application perspective? The result was ambiguous and error prone, and the solution were to add another entity, *connectivity.* Further enhancement was also underway and subcategories derived from literature were added to improve the usability of the analytical framework. An extended version of the framework with four central entities and one implicit entity, *organisational settings*, was in place (see figure 15). This version of the accentuated factors framework was published in Andersson and Henningsson (2010b).

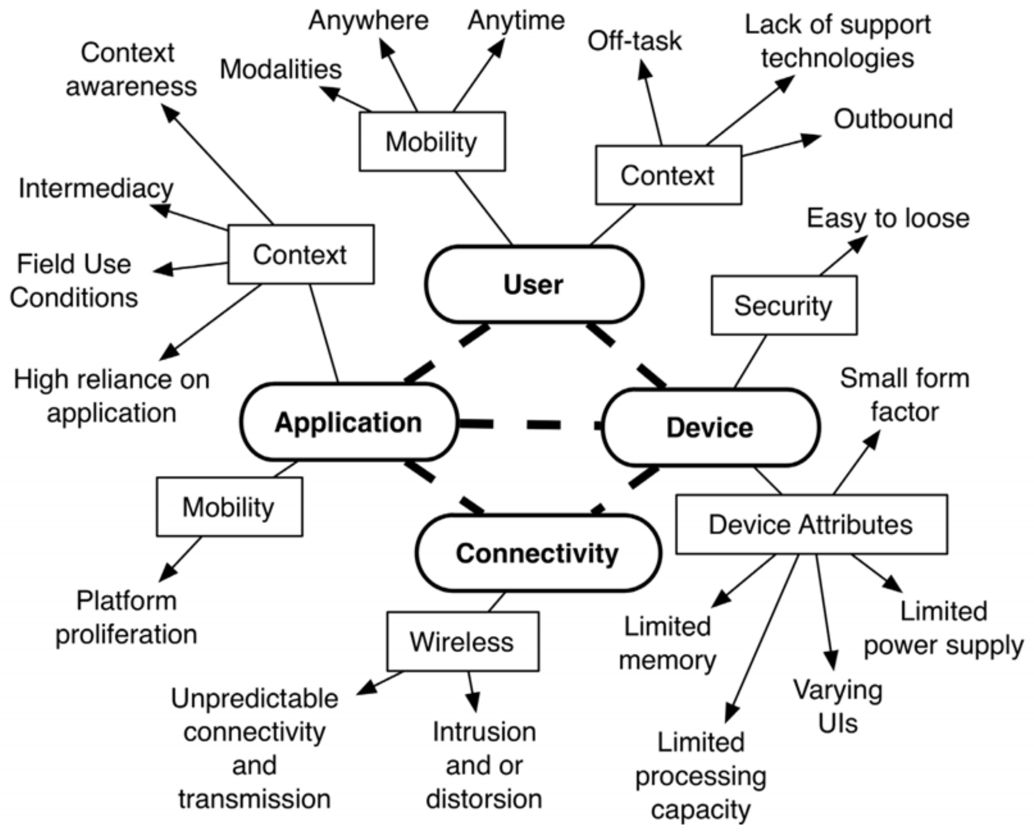

Figure 15. Further developed framework with the additional entity of connectivity and also visualising properties of the factors, presented in Andersson and Henningsson (2010b). The bold and dotted edges between entities imply a possible overlap between entities. Between Connectivity and User are no edges, illustrating that problems with connectivity do not directly affect the user, but via the two other entities. The factors are in rectangles and the directional arrows points towards properties. However, the use of directional arrows can be questioned because they may cause ambiguity in interpretation.

However, during work with latter versions of the framework, three major problems with this framework and its graphical representation were identified via reviews, conference presentations and seminars, and my own analysis of the framework.

One problem was the graphical representation; the arrows, entities, and different formats of the entities raised questions on interpretation and caused unsought ambiguity. Another problem was the distinctiveness; some factors had overlapping properties. Finally, there were problems concerning the labels of the factors in that some were not proper factors but values on some scale. In order to manage these shortcomings, the solutions were to conceptually cleanse the terms into more distinct factors and to discard the neat graphical diagram and instead use an alphabetically ordered list of factors (see table 13 in section 2.6).

3.4.2 Knowledge gaps in tentative framework

As explained in paper 1 (Andersson 2010), the purpose in the paper was to examine available research to gain a better understanding of the present situation in the field of mobile computing (Webster and Watson 2002).

The framework was built on the three dimensions; the tentative accentuated factors framework; design science approach or not and organisational settings. Journals were selected by applying a selection strategy of impact factor and other ranking systems, as suggested by Mylonopoulos and Theoharakis (2001) and Peffers & Ya (2003). The main reason for only selecting journals was that journal articles are often considered as being of higher quality and rigour compared to conference papers. Another argument was that high-quality and relevant conference papers are published in journals.

Abstracts were searched using the search phrase "(mobile OR mobility) AND (application OR development OR developing OR design OR designs) AND NOT (algorithm)".

It was a deliberate choice not to include the factors in the tentative framework in the search phrase because that most likely would reduce the set of publications. Instead the more general search phrase (above) was used. However, in the set of publications identified in the databases the factors were used as a theoretical model to select publications. By this new concept could be identified, concepts that may hade been excluded if the factors were used in the search phrase.

The obvious limitation of skewed results due to selected outlets is discussed in the paper, a limitation that is difficult to avoid unless all existing outlets are surveyed, however that would be too labour-intensive. In retrospect, using the design science approach and using “design or designs” do also skew the result. By applying that search term, it most likely skewed the results towards design papers. The “development OR developing” term would also skew the results in favour of design papers. Design or prescriptive approaches account for 52.9% of the results, indicating an even distribution; however, this distribution could be questioned.

3.4.3 The retrospection literature review

As explained in paper 8 (Andersson 2012b), the purpose of the paper was to identify worthwhile areas for further investigation (Webster and Watson 2002).

Paper 8 strongly resembles paper 1 because they were both literature reviews applying the accentuated factors framework, although different versions of the framework. This paper differed from paper 1 by an updated set of publications, an extended set of outlets, and a refined analytical framework. The outlets were not only top mainstream information system outlets as in paper 1, but extended with a broader and more specialised set of outlets based on Hu et al. (2010) and Ladd et al. (2010), and lists of major mobile computing outlets, a strategy supported by Webster & Watson (2002). Although still not selecting conference publications, based on the same argument as in paper 1, skewed outlets should be less of a problem compared to paper 1 due to the enhanced selection process of outlets.

The applied search phrase was “(handheld OR mobile OR mobility) AND ((design OR designed OR designs OR developing OR development)) AND NOT (algorithm)”.

Due to inconsistent results in the Lund University database LibHub (the successor to ELIN), making it impossible to replicate the search made in paper 1, databases provided by ACM, Palgrave Macmillan, Taylor Francis, Springer Verlag, IEEE, Informa, Ebsco, IGI, and Elsevier were searched as replacements.

In paper 1 a distinction was made between descriptive and prescriptive in order to identify design-oriented research. This distinction was, in retrospect, ambiguous whereas the expected outcome should skew towards design-oriented papers. In this paper, the "design aspect" was modified into a type V theory (Gregor 2006), thereby mitigating the aforementioned problems with ambiguity with the concept of design occurring in paper 1. Regarding use of the framework factors in the search phrase, the same argument as in the first literature review was put forward.

3.5 Case presentations

This section presents what kind of organisations where the data collection was made.

The rationale for presenting the case in this section is that knowledge of the cases is valuable before reading about the method applied in the cases. That is, the placement of the case presentation in the dissertation is a deliberate choice in order to enhance the readability of the text, an ambition supported by Suddaby (2006).

Three organisations with different operations were studied, one on the development of a backend system, one on the development of a backend/frontend system, and one on the use of a frontend system.

3.5.1 21st Century Mobile Solutions

The purpose of 21st Century Mobile Solutions (21st CMS) is to provide a more thorough analysis of aspects regarding design and development of a backbone system handling communication to and from handheld devices. 21st CMS case is a longitudinal study during the development of a communication platform.

The firm 21st Century Mobile Solutions is a service provider in the Nordic market offering a gateway between mobile phones, mobile networks, and computer networks. The company had at the time of writing 12 employees and two offices, sales and marketing in Stockholm (4 employees) and research and development in Lund (8 employees). During 2005–2008, the company developed in-house the SMS platform myMSP.

The offering to customers is the distribution of high-quality and large traffic loads SMS and MMS to and from server applications and related services such as automatic reminders, broadcasts, monitoring, and alerts.

The motive for the system is to reduce the high interconnect fee that originated when the operators ported SMS from one operator to another. This caused an interconnect fee that can triple the cost of the actual SMS. By assigning all mobile operators in Sweden and using a PTS routing database, the interconnect fee is avoided.

The system developed is a server solution interconnecting TeliaSonera, Vodaphone, Tele2 and TRE and offering interfaces to ERP systems, Outlook clients, web servers, etc. Due to the fact that all operators are interconnected, myMSP is able to manage both *short numbers* and *aliases*. A *short number* is an operator-specific number mostly used for premium SMS and MMS, whereas *aliases* are alphanumerical replacements of the sender's number. In figure 16, a schematic view of message traffic is displayed. Products based on the server solution are such as Dental Care reminders, Staff Planner, Incident Management System, Mobile Payments, Mobile Tickets et cetera.

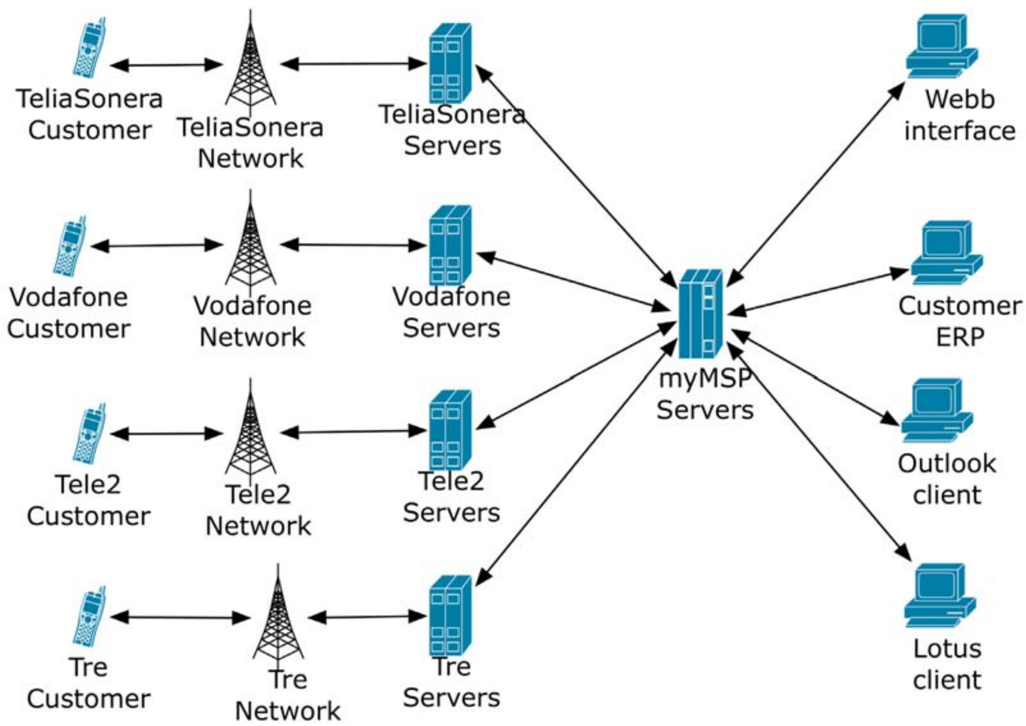

Figure 16. The message flow in the myMSP platform. The platform interconnected the mobile phones (via mobile operators) to computer networks and computer based information systems.

3.5.2 ASPEA Mobile

The purpose of ASPEA Mobile is to provide a more thorough analysis of the developer's experience from the design and development of an application for the mobile workforce.

The firm ASPEA Mobile is a development company located in Lund, which had three employees at the time of writing. The employees have a long history of software development, ranging from the time of mainframe computers to personal computers and further on to handheld computers.

The offering to customers is WinHast, a logistics platform for the management and optimisation of Service-Travels. In Sweden, the County Councils offer service travels to their citizens, which involve the transportation of people to and from healthcare units. Local transportation companies such as bus companies and taxi companies perform service travels.

The motive for the system is to reduce the cost of transportation by better utilisation of passenger capacity in cars and buses. There were considerable redundancies or overlaps in transport prior the WiHast system. Cars often transported only one passenger at a time, and this was considered a major problem to solve.

The system developed is a complete system for management and optimisation of transportation. At the time of the study, the WinHast server application served approximately 210 drivers equipped with handheld devices. The handheld device is a Mio A710 smartphone with Windows Mobile 5.0 connected to the WinHast system via mobile carrier networks. Approximately 3,000 driving assignments per day are handled at the time of writing. The handheld application comprise three modules: the actual WinHast application, a GPS module, and a GPRS module. An additional application bought from a third party supplier is installed for remote management. The developers works closely with the customer (Kalmar County Council) and the end-users (the drivers and dispatch staff) using an iterative approach.

The supported workflow is twofold, supporting dispatch staff in optimising transportation and relieving drivers form error-prone routine tasks. The dispatch staffs administer booking and invoicing. One of the administrators' tasks is to optimise the transportation in order for the vehicles to transport as many clients as possible at the same time. This is achieved by route optimisation and just-in-time adjustments on planned routes, tasks that WinHast supports. WinHast monitors all vehicles on duty, recording vehicle position via GPS and logging the mileage, destinations, and a set of important parameters such as connectivity, keystrokes, charging, etc. A billing function is also included, calculating mileage, time, and fares. Below is a screen shot of the interface available for the dispatch staff (figure 17). The system helps drivers with navigation, and pickup and termination of driving assignments are automated by the handheld information system (see figure 18).

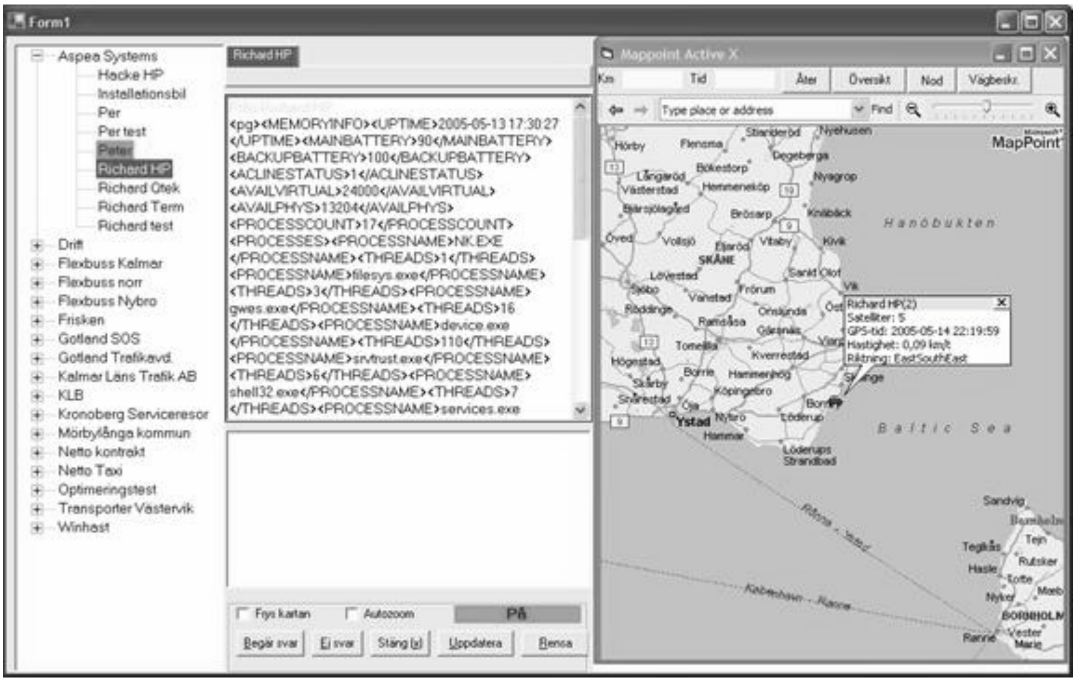

Figure 17. Screen shots from the Winhast Logistic system view showing different transportation companies and monitoring of car locations. Via this interface all cars and drivers on duty could be monitored.

Figure 18. Screen shot from the WinHast application installed on taxi drivers' PDA's, displaying the driving assignments.

3.5.3 ACME

According to agreements with the managers, this organisation is kept anonymous and the fictive name ACME is used.

The purpose of ACME is to provide a more thorough analysis of user's experience of a handheld information system. The users at ACME are digital rangers with experience of using a computerised information system to support their work processes.

The firm ACME is the Swedish subsidiary of a large international firm that operates in haulage, heavy industry, machinery, and transportation. ACME employs roughly 450 people and has revenue of approximately 1 billion SEK.

The offering to customers is ambulatory repairs and maintenance of material handling equipment bought from ACME.

The motive of the system is to reduce the time from service order creation to invoicing the client. Before implementing the mobile information system, the time from service order creation to invoicing the client was on average 2–3 weeks and occasionally up to four weeks. After the implementation of the mobile information system, this time is reduced to 2–3 days and at the most four days.

The system developed is a frontend solution offering a connection to ACME's ERP system via GPRS and a middleware parsing data to and from the field to apply to the ERP data (see figure 19). About 300 ambulatory service technicians are equipped with sturdy PDAs with installed software (see figure 20).

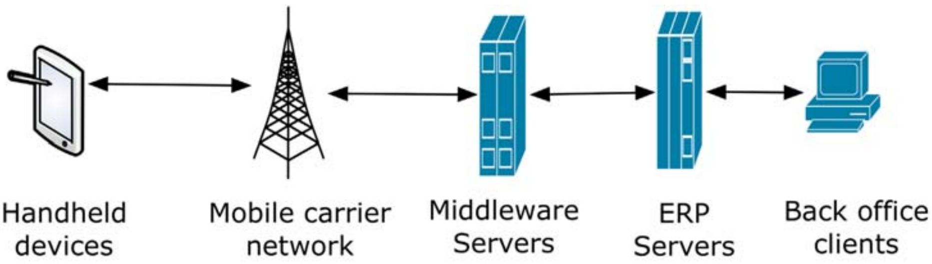

Figure 19. The communication flow in the installed information system at ACME. On the middleware server the message to and from the ERP servers were parsed to fit the recipient.

The supported workflow is chiefly that of the service technicians. The service technicians are digital rangers, i.e., without a traditional home base. They leave their homes in the morning, receive assignments via their handheld devices, and drive small trucks with a small workshop and a supply of spare parts to the customer facility. Service orders and spare part ordering are carried out via the handheld information system.

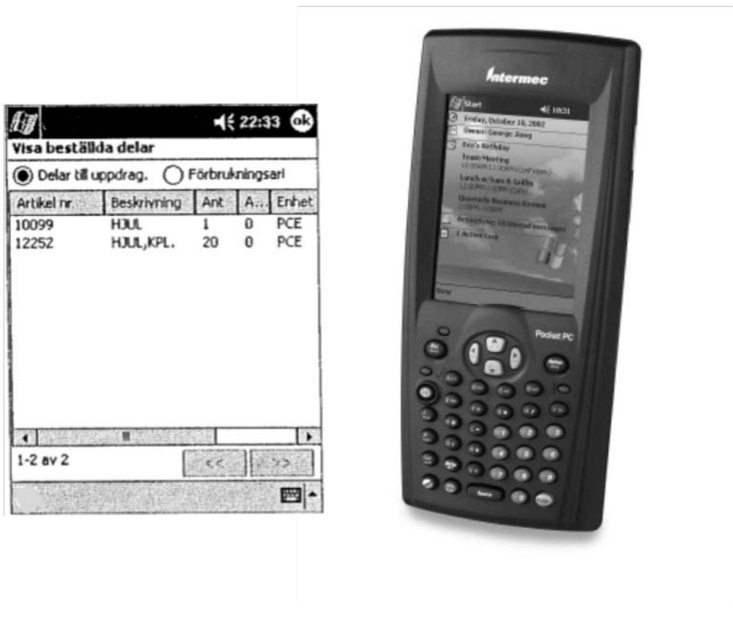

Figure 20. To the left a screen shot from one of the applications at ACME and to the right the Intermec 700 handheld device used by service technicians at ACME. Pictures from ACME manuals.

3.5.4 Reflections on the case studies

When studying different cases the aspect of transferability is usually discussed, meaning that aspects in one case may be comparable with similar aspects in another case (Lincoln and Guba 1985). However, it is not the aim of this study to compare different cases but to cover more aspects of handheld computing. With these three cases a chain is discernible, from backbone to end user, with specific aspects and findings shedding light over a variety of aspects. Although not comparable cases, information from one case may inform considerations in another case, for example, use of applications in the ACME case may inform designers building applications for the ASPEA Mobile users.

The choice to apply a case study strategy is based on the arguments that a case study is appropriate when the phenomena are situated in a real life context, when the researcher is unable to influence events, and when the phenomena are contemporary, see for example: Silverman (2006), Starrin and Svensson (1994) and Yin (2003), arguments which are valid in this dissertation. This decision is further supported by the fact that there is a lack of comprehensive frameworks or theories on handheld computing, and case studies have been proven appropriate when theories are underdeveloped (Dubé and Paré 2003, Yin 2003).

The case selection was based on gaining a broad coverage of aspects. In the 21st CMS case, the focus was on the server system serving handhelds. In the ASPEA case, the focus was on handheld applications backed up with server systems. In the ACME case, the focus was on the application situated in an organisation and used by fieldworkers. When equivalent cases are selected, there is less likelihood of finding different aspects.

Although they are three different cases, with different objects of study, they do have something in common: the approach in all three cases is of a qualitative nature. What is searched for is a deeper understanding of the character and quality of handheld computing, and quantitative measurements are, for the time being, out of scope. In its place, qualitative and interpretive approaches are considered more appropriate, see for example: Klein and Myers (1999), Silverman (2006), Starrin and Svensson (1998). Furthermore, case studies combined with interpretive approaches have proved successful in a considerable number of research projects within the information system field (Benbasat et al. 1987, Walsham 1995).

An alleged disadvantage of interpretive case studies are problems with generalisability (Cavaye 1996). However, generalisability as conceived in the mainstream of research may not be a valid quality indicator for interpretive studies (Denzin 1983). One can argue that generalisability is a legacy of a natural scientific paradigm, not applicable in design science. Lincoln & Guba (1985) instead advocate the notion of transferability, the ability to move a conclusion from one context to another. With the interpretive stance of this work, the interpretation of generalisability as statistically sound extrapolation to a larger population is inappropriate.

3.6 Collecting, analysing, and using empirical data

This section describes how empirical sources are used to fulfil the dissertation aim. Due to the multifaceted unit of analysis, a set of different data collection methods is used (Hevner and Chatterjee 2010, Marshall and Rossman 1998).

This study involves three *cases studies* used to extend the tentative framework with new accentuated factors and to find design propositions. It also involves *semi-structured interviews* to evaluate and extend the tentative framework and *quasi-experiements* to evaluate the toolkit developed.

3.6.1 Collecting and analysing data from 21st CMS

As explained in paper 4, the 21st CMS case was a longitudinal case study (Yin 2003) in which the object of study was the development of a mobile communication platform (see section 3.5.1 for case description).

The focus was on the technical issues related to the development of the system and the aspects of interconnection with handheld devices. The study was mainly done from the perspective of the developing firm. The main method used was participating in the design and development process and in the communication between the developers and the mobile operators' technical staff and recording data via field notes and via project management software (see figure 21 for a sample from the project management software). Although it was a longitudinal study where I participated in the development as a supervisor, it should not be perceived as action research because the aim was not to change or intervene with established practice (Edwards and Talbot 1994). Instead, it should be considered as a partaking observation (Bryman 2001). Document studies were made to verify the information from workshops and interviews, documents in the form of service-level agreements, database schemas, source code and application programming interfaces, and data aggregated in matrices. See appendix 7.2 and 7.3 for informants, time spent on interviews, documents etc.

As a complement, interviews with developers at 21st CMS and technical staff at the mobile operators were done in order to clarify and avoid any misconceptions from workshops, development, and data recorded by field notes (Lincoln and Guba 1985).

Namn:	SMIL-filerna: Hur lösa detta???
Id:	30
Steg i arbetsflöde:	Ska genomföras
Prioritet:	Mycket Hög
Ansvarig:	Mats Revesjö
Status:	Inte startat
Ärendetyp:	Ändringsförslag
Senast ändrad:	06-07-22
Beskrivning:	BA 060110 SMIL Detta är ett större projekt som måste hanteras för sig. Går det att pinga operatör för att ta hem mobiltyp. Reversed engineering, hur ser SMIL ut som kommer till operatören Uppenbarligen har 3 (Tre) löst detta och Carl är nu uppjagad över att vi inte har fixat detta. Enligt Wikipedia ligger ansvaret för content-anpassning på mottagarens MMSC. Detta medför följande frågor: Kommer content-anpassningen bli bättre när vi använder MM7, funkar content-anpassning i dagsläget illa på testmobilen iom att Telia (operatören) inte har en MM7 MMSC, funkar anpassningen egentligen - bar det att bilden i sig inte kan bli bättre på en skärm med den upplösningen... (BA 060114) Parsing av bilder i MMS-editorn
Dokument:	

Kommentarer till *SMIL-filerna: Hur lösa detta???*:

1) *(Bo Andersson, 06-07-22)*
Har beställt att Levonline ska uppgradera vår server. De ska bara svara när de vill/kan så att vi kan synka med nedsläckning av servern. Någon linux-guru vore välkommen...
2) *(Bo Andersson, 06-07-22)*
Tre har en färdig editor för MMS, som deras kunder kan använda.
3) *(Mats Revesjö, 06-07-21)*
Vad är det 3 (tre)
har löst?
4) *(Mats Revesjö, 06-07-20)*
För hantering av
bilder under Linux
bör vi snarast gå
över till JDK 1.5.
5) *(Bo Andersson, 06-07-11)*
Höjd prioritet
6) *(Bo Andersson, 06-06-30)*
Kolla upp med operatörerna

Figure 21. Sample of data captured from the project management software Projectplace. The sample regards an errand related to the SMIL-file and the SMIL format.

The analysis was based on a grounded approach where the empirical observations provided the basis for further analysis (Yin 2003). In the workshops and development process, certain aspects were identified and discussed. These aspects guided the development of important factors that merited further study. As mentioned earlier in this section, documents in the form of service-level agreements, database schemas, and source code were analysed to confirm the findings of workshops and interviews. Due to the nature of these documents, the traditional analysis methods were not applied. I was not aiming to analyse narratives or perform ethnographically inspired analysis as described by Silverman (2006). Instead, I made a “confirmatory reading”, where the problems discussed in workshops were distilled down to a few concepts, and with the ambition to ensure validity of data from workshops a triangulation by confirmative reading were conducted.

The following is an attempt to portray what I mean by a confirmatory reading: Imagine you are a tourist lost in a city. You have a good city map but are unsure of your present location and in which direction to go. You ask someone for help. This person marks your present location on the map and then gives you directions (without using the map). Afterwards you look at the map to *confirm* the spoken instructions, hence, doing a confirmative reading. By a confirmative reading you can estimate the degree of accuracy in the spoken statement.

Hence, by studying software, documents or other artefacts it may be possible to confirm or refute spoken statements. For example, an informant may argue that there is a problem in relaying data between two services because incompability between data formats. This could be correct, or it could be a mistake on the informant behalf due to some unknown cause. With a study of technical specification it is most likely possible to confirm or refute that statement. By doing this the information on incompability between data formats are no longer a subjective opinion from an informant that easily can be questioned by some statistical argument, but a reasonably reliable piece of data.

3.6.2 Collecting and analysing data from ASPEA Mobile

The next case was the backend/frontend system for transportation logistics developed by ASPEA Mobile (see section 3.5.2 for case description).

The basic method was interviews complemented by demonstrations and document studies to further improve the data on the developed system. Five phases where each step further improved the data were performed. Phase 1 involved attending a presentation of the system, focusing on the lessons learned during the seven year of development, and recording data via field notes. In Phase 2, interviews were performed with one developer and one sales manager, and data were recorded via field notes. Phase 3 involved document studies on the developed system, and data were recorded via field notes. Phase 4 involved telephone interviews with the developer and dispatch manager, and data were recorded via field notes. In Phase 5, semi-structured interviews were made with two developers, and data were recorded via field notes. At this time I requested permission to record the interview, but due to patient secrecy this was not granted. For more information on time spent on interviews etc., see appendix 7.2, 7.3.

Data analysis for the ASPEA Mobile case was performed when the tentative framework existed and the tentative framework together with *lesson learned* put forth at the first presentation provided sensitising concepts (Schwandt 1994) that were used in the analysis. First the data were categorised into overarching themes. These themes were deconstructed into smaller themes and categorised according to the tentative framework, a suggested by Miles and Huberman (1994).

Categories not related to handheld computing were removed, and categories relevant to handheld computing but not present in the initial list of accentuated factors extended the list of factors. To strengthen the validity of data from presentations and interviews a confirmative reading were conducted.

3.6.3 Collecting and analysing data from ACME

The third case was on the use of a frontend system for service technicians at ACME (see section 3.5.3 for case description).

As in the previously presented cases, several methods were applied and different types of data were collected. Interviews, demonstrations, document studies, and artefact studies were made in order to draw a rich picture of the use of ACME's service order system. The informants were service technicians, dispatch staff, and managers. Data were in the form of field notes, photos, copies of digital and written documents (see appendix 7.2 and 7.3 for more information on interviews, documents etc.). The chronological order of the data collection was as follows. In Phase 1, a user demonstrated the information system, and data were recorded via field notes. In connection to this demonstration, system documents were acquired. In Phase 2, manuals, handbooks, and teaching materials were studied, and data were recorded via field notes. Knowledge from Phase 1 was used to interpret the documents, and a confirmative reading was conducted.

With input from Phases 1 and 2, a process model describing the workflow in the mobile information system was constructed. This model was used as a backdrop in the forthcoming collection of data.

In Phase 3, a second observation and interview were carried out, and data were recorded via field notes and photos. It was realised that only asking one informant could skew the findings if the informant was the only one with this opinion, therefore additional interviews and data collection were carried out. By this, triangulation was conducted (Lincoln and Guba 1985). In Phase 4, a telephone interview with a manager was carried out, and data were recorded via field notes. The manager recommended other service technicians to interview based on their knowledge of the information system. Phase 5 involved telephone interviews with four service technicians using a semi-structured questionnaire, and data were recorded via field notes. Phase 6 involved a telephone interview with a manager on perceived workflow change for users, and data were recorded via field notes.

Regarding analysis, the basic perspective was a developer's with an interest in possible lessons to be learned from the implemented solution. Sensitising concepts such as *structural features and spirit* were used in conjunction with *appropriation* (for a more detailed description of concepts see Andersson (2008)). The sensitising concepts *structural features and spirit* related to how restrictive the system was for alternative actions, the degree of complexity in the application, the number of features in the system, efficiency, and formality. Furthermore, *appropriation* related to the direct use, relations to other structures, and constraints to structure, and judgements on structure.

3.6.4 Practitioners' opinion of the tentative framework

Below is a description of how the evaluation of the tentative framework was executed. The major part of the method is presented in the appended paper 2 (Andersson and Henningsson 2011). Here additional details are presented.

The evaluation criteria for analysis suggested by Gregor (2006) was applied. According to Gregor, the usefulness of this type of theory can be evaluated based on its completeness, distinctiveness, and simplicity. The evaluation was performed via interviews with experienced practitioners (see appendix 7.2 for years of experience). Via searches within the LinkedIn.com network (Linkedin 2012), practitioners with experience of handheld computing were approached. No informants that I had any previous contact with were used. If practitioners showed an interest, they were informed about the purpose and content of the interview, and if they considered themselves able to contribute a date and a place were set. 12 of the interviews were done at the informants' workplaces and 4 interviews at my workplace. The interviews had an average duration of 1 hour and 30 minutes.

The first phase of the interview was an open-ended discussion on the nature of handheld computing and perceived differences between desktop and handheld computing from a designer/user perspective. The second phase regarded the tentative framework, and the discussion in the first phase was mapped into the tentative framework. In the second phase of the interview, cards describing the factors were handed out to the informant (see figure 22), complemented with blank cards that could be filled in with new factors. By this two phase strategy I could collect data from the informant with active listening and letting the informant describe handheld computing with the informants own word (Silverman 2006). In the latter parts of the interview, the form became more structured allowing for a more detailed conversation revolving the factors. The argument for deciding on semi-structured interviews was that the phenomena of handheld computing were under investigation, its properties and qualities (Silverman 2006). Taken together the interviews revolved around what the informant considered to be significant in the design of mobile information systems; differences between handheld and desktop design; the importance of the factors derived from literature, and the applicability of a framework as such (see 7.6 and 7.7 for questionnaire). In total, sixteen interviews were carried out and in order to achieve some sort of validation on suggestions, from the second interview and forthcoming interviews information from the previous interview was briefly discussed in the rest of the interviews, by this performing sort of a member check (Lincoln and Guba 1985).

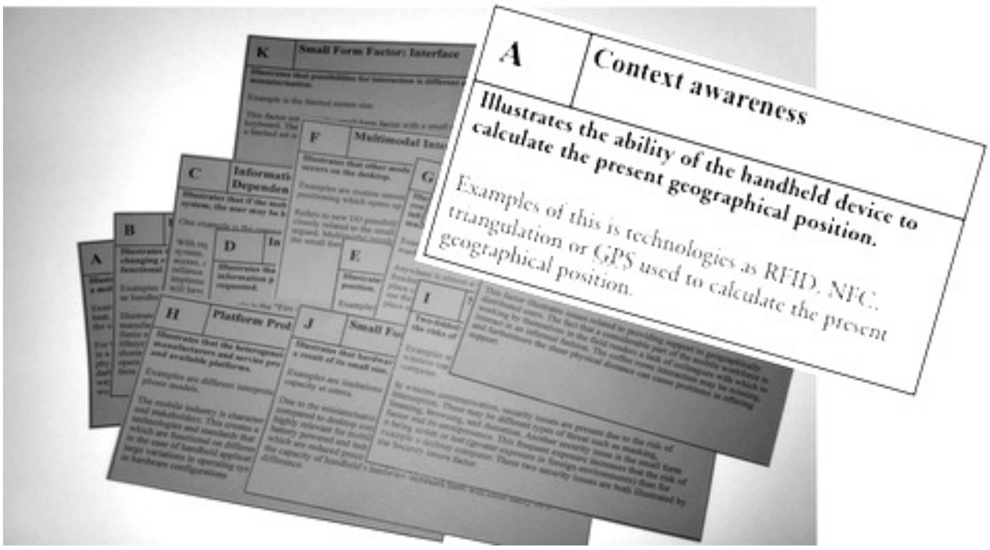

Figure 22. The accentuated factor cards, one card highlighted in order to enhance readability.

All interviews were recoded and transcribed. After each interview, transcriptions were coded into groups related to factors and analysed chronologically in order to identify possible saturation. Saturation here indicates that no additional, unknown comments or suggestions regarding the three evaluation criteria came up during the interview, and saturation was reached after five interviews.

Thanks to saturation, after nine interviews the interview guide was slightly modified, aiming to improve data collection regarding dependencies between factors. However, the modified interviews still involved the factors and were possible to analyse in line with the preceding nine interviews, see appendix 7.7 for revised questionnaire. The main difference was that the informants were asked to describe which factor influenced which factor in a real case that they had experience of. They were handed a diagram (see figure 23) where they could illustrate dependencies and naturally explain the nature of the dependencies.

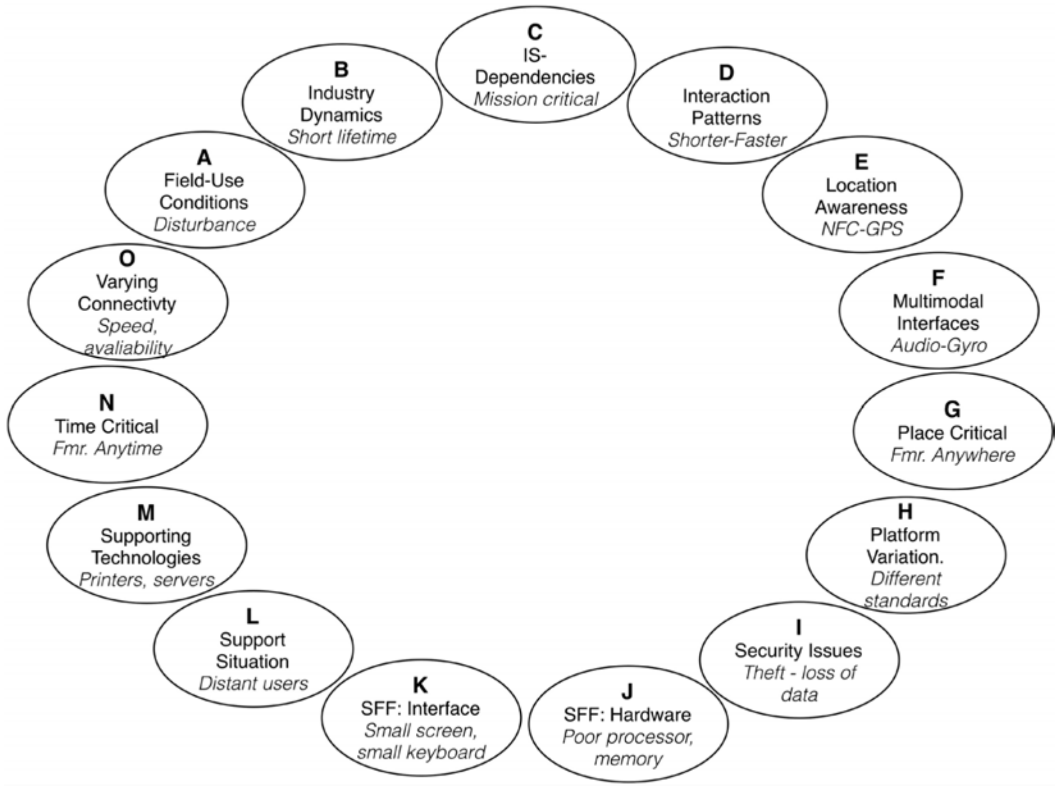

Figure 23. The diagram presented to the informants where they illustrated dependencies between factors. Block letters in diagram corresponds to HISD Cards and table 21. The informants were asked to draw lines between related factors and to explain the relations, relations that further on analysed if being dependencies or not. These diagrams were combined with interview transcripts in the analysis.

To create codes and support analysis, the qualitative data analysis software HyperRESEARCH (Researchware 2012) was used during analysis. The transcribed interviews were uploaded into HyperRESEARCH and the transcripts were coded (see figure 24 for excerpt). During analysis 90 different codes were created, for example: *place dependencies*, *time dependencies*, *completeness*, *expected user*, *overlap*, *form-factor interface, active behaviour, wicked problems, quality insurance, high complexity, problems with development frameworks*, and so on. These codes were grouped in sets of codes and were evaluated in relation to the existing tentative framework.

Figure 24. This excerpt displays part of a report in HyperResearch; the code "varying connectivity" is applied on code block 9646.10006.

3.6.5 Finding dependencies between factors

Below is a description of how the internal dependencies between the accentuated factors were identified in the data. A considerable part of the method is presented in the appended paper 3 (Andersson 2012a). Additional details are presented here.

In the search for dependencies between factors in the accentuated factors framework, more or less all existing empirical data were reanalysed. To sum up, data from 32 interviews were analysed, sixteen interviews with experienced practitioners; seven interviews with developers; and nine interviews with the users of a service order system. Documents from the three case studies (21st Century Mobile, ASPEA Mobile, and ACME) were also analysed in the search for dependencies between factors.

Regarding internal dependencies between factors, the data were analysed in relation to the accentuated factors framework, an analysis supported by HyperRESEARCH software (see figure 25 for excerpt). If one of the factors in the framework affected another factor, a dependency was noted. In this analysis, no further considerations regarding the strength or nature of dependencies were made, i.e., whether it was a reinforcing or disruptive dependency. The results were arranged in a table showing the depending and dependent factors and the number of influences (see table 22 in section 4.1.5).

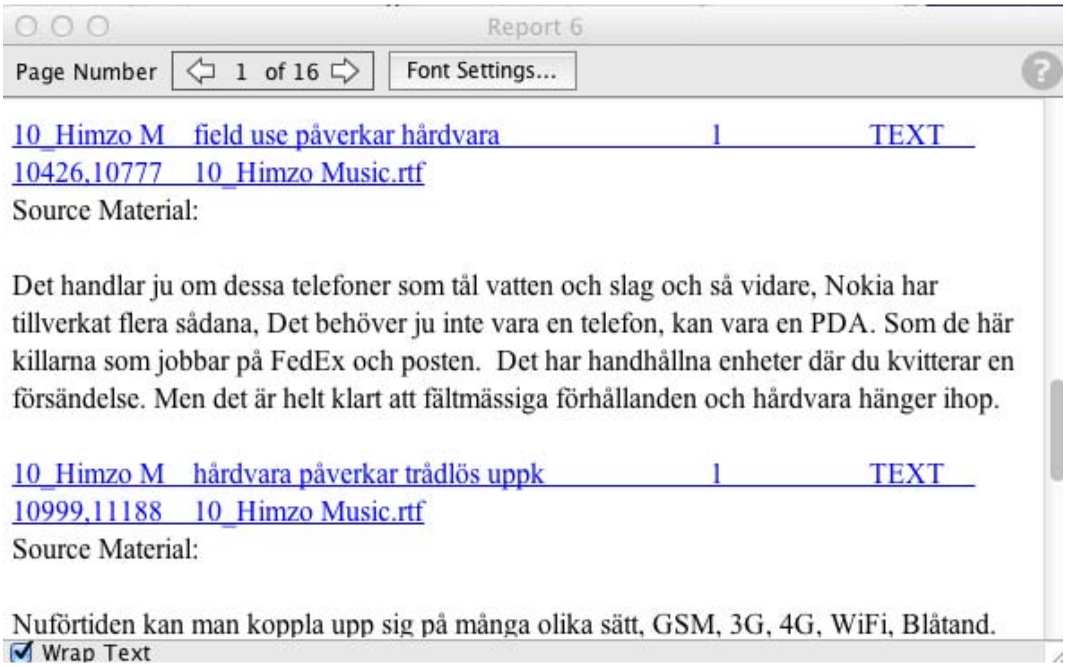

Figure 25. Excerpt from HyperResearch software. In this sample, the relation between field-use condition and small form factor hardware is mentioned.

To further analyse dependencies and to identify central factors, the visualisation software Graphviz (Graphviz 2012) (Ellson et al. 2003), along with the Neato scheme (Gansner et al. 2005), was used to draw the diagram and was filtered using SCCMAP.

3.6.6 Students as HISD Toolkit test pilots

In this section the Handheld Information System Design Toolkit (HISD Toolkit) evaluation is described. This work is not presented in any paper; therefore a more thorough presentation of the method follows.

During the first nine interviews regarding the evaluation of the factors, the informants were asked how a framework as such should be presented: "*Who could be a potential reader of a framework as such?*" and "*How should the framework be presented/illustrated/displayed to a potential reader?*" Based on an analysis of the answers of these questions the HISD Toolkit was developed. In short, a method based on agile methods and the evaluated comprehensive framework was developed; see section 4.2 for motive on design. Below is the evaluation described, not the creative process of figuring out the details of the method.

The toolkit was evaluated by quasi-experiments with master students in information systems design. The design of the quasi-experiment were inspired of the nonequivalent group, posttest design (Gribbons and Herman 1997), however without the quantitative analysis as covariance analysis (Shadish and Thomas 2002). Instead a more qualitative approach where applied in the analysis. The evaluation may have similarities with the workshop method, however, I judged workshop as not suitable due to mainly one reason: I wanted to study *form* rather than *content*. That is, the aim was to investigate if differences in the HISD Toolkit caused differences in process or output. My role was more as an observer than a participant and the main source of data was the notes taken in the first round of experiments and with audio recordings in the second round of experiments. The ambition was not to rely too heavily on the participants opinion on the toolkit or the factors. However they were asked questions regarding the method but it was not the prime target. If evaluating the HISD Toolkit on content properly, it should be used in a real design and development project, see section 5.3.2 for a discussion on this.

The main reasons to use quasi-experiments and not proper experiments was the problems with interfering factors and the selection of participants. In a proper experiment one should reduce the interfering factors plus the participants should be randomised, and there is a strong reliance on control of all variables (Shadish and Thomas 2002). In the case of HISD Toolkit evaluation this was not considered feasible.

The independent variable was the start arrangement of the accentuated factors and aspects revolving the dependent variables *outcome*, *ease of use* and *speed* were elaborated on.

Outcome, any differences in the finalised arrangement of the factors? *Ease of use*, was the instructions easily interpretable. With *speed*, were there differences in the start-up of the experiment? Could differences in time to accomplished task be discernible? With information on these aspects the most appropriate start arrangement could be decided on. Furthermore, aspects not considered in advanced may surface during analysis.

The experiment started with a two-hour lecture on accentuated factors. After the lecture, each group (groups 1–3 in figure 26) was supplied with a set of HISD-Cards (see figure 28), two case descriptions and instructions how to use the HISD-Cards in the experiment (see appendix 7.8 for the instructions and case). The differences between the groups were the start arrangement of the cards. Group 1 had instructions to arrange the cards based on empirical findings on dependencies between factors. Group 2 were not instructed to any predefined start arrangements and group 3 had instructions to arrange the in a circle (see figure 27).

The three groups worked on the assignment simultaneously for one hour, and my role was to oversee and facilitate the session, supported by one assistant taking notes and taking photos (a colleague researcher).

At the end of the session, the models were recorded (see figure 29 for an example), the three groups were merged into one group, and the perceived usefulness of HISD Toolkit was discussed as well as problems with the toolkit. Differences between groups' perceptions was noted.

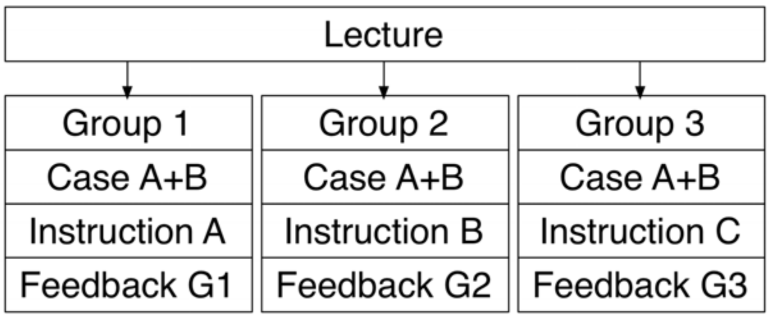

Figure 26. The structure of the first experiments in which the three groups worked simultaneously with different instructions (A, B, and C), although with the same cases. All group members attended a lecture, afterward the sessions were discussed with each group.

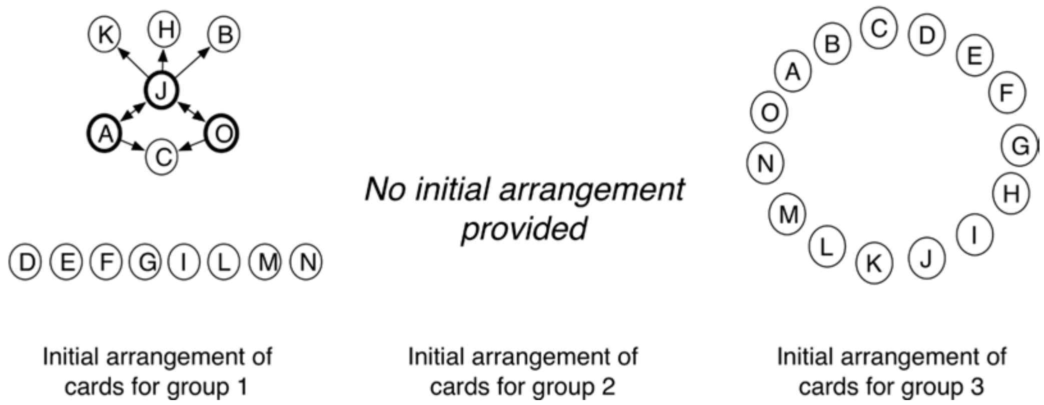

Figure 27. The proposed start settings of factors in the first round of experiments. Settings for group 1 were based on findings on dependencies between factors. Group 2 was not given any instructions on start settings. Group 2 and 3 were control groups.

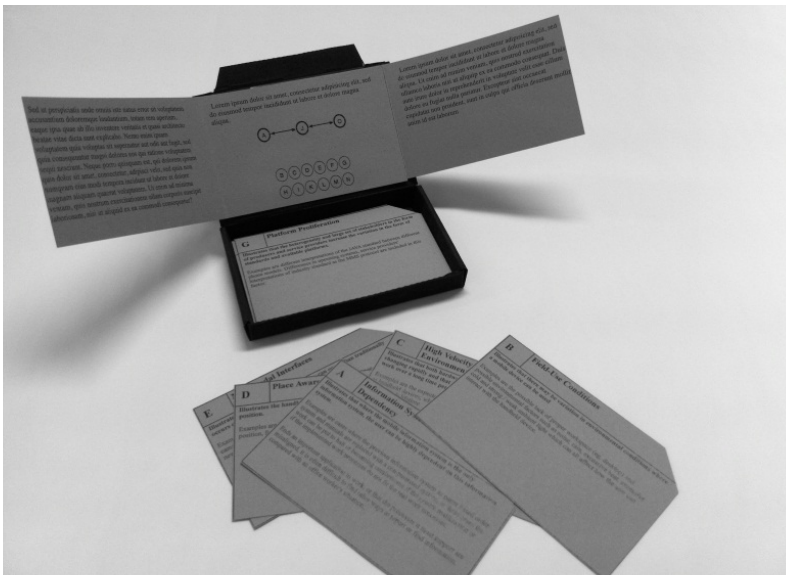

Figure 28. First mock-up version of the HISD Toolkit, a box with instructions inside the top lid and the set of HSID cards

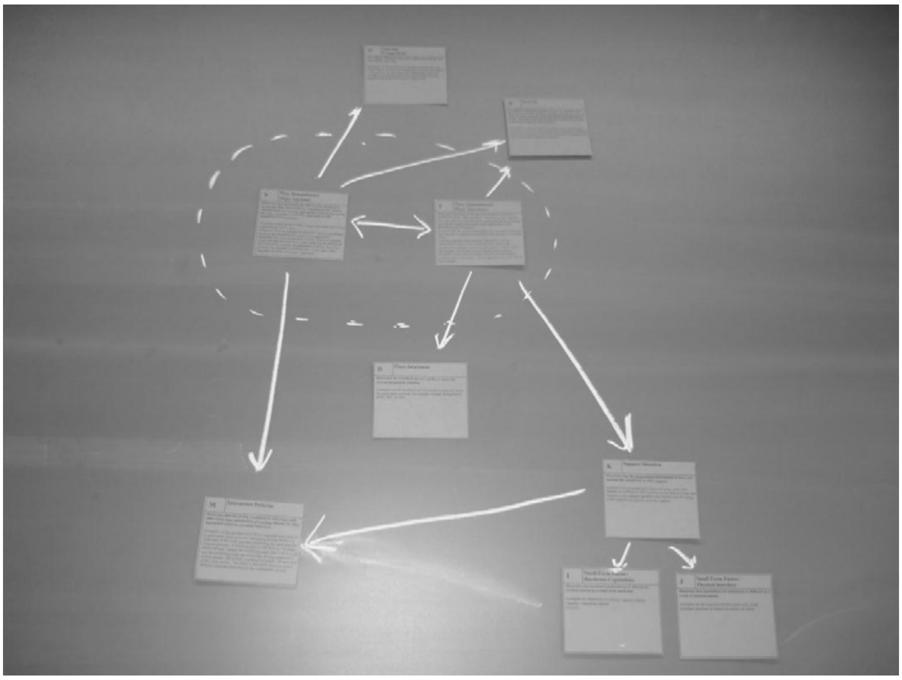

Figure 29. Photo from workshop 1, group B. The factors in the dotted circle were considered as critical and the directional arrows described assumed dependencies.

After experiment 1, an analysis of the evaluation was made and the planned second round of experiments was modified. At the second round of experiments the instructions were slightly enhanced (see appendix 7.9 for revised instructions); however, the main themes were identical. Instead of two simple cases, a single, more elaborate case was used (see appendix 7.10 for case description), and the start settings were modified (see figure 30).

However, the two major differences were that the settings with three simultaneous group sessions were replaced with a sequential order, and my role changed from facilitator to a fictive customer with domain knowledge, although still not participating in the building of the model. Data were recoded via video, photos, and field notes (see figure 31 for snapshot from workshop 5).

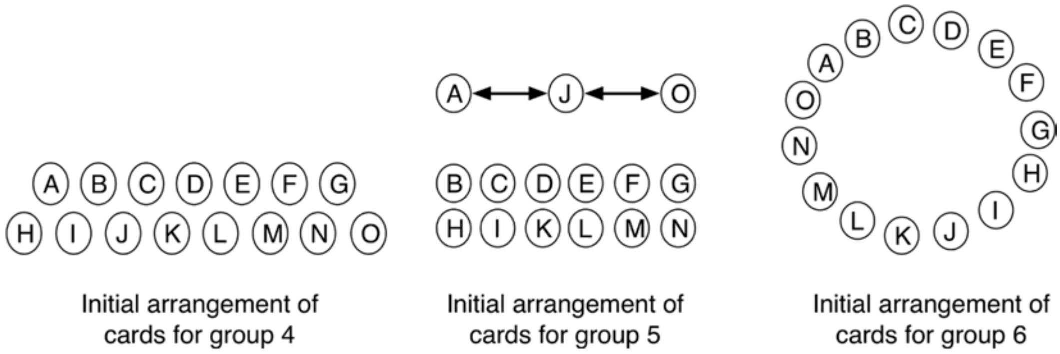

Figure 30. The initial settings proposed in workshop 2; settings for group 5 are based on a reduced set of empirically identified dependencies. Group 4 and 6 were control groups.

Figure 31. Snapshot from the second round of experiments, group 5. The test pilots were discussing the importance of *support issues*.

After the second round of experiments the data were analysed in order to find out what differences in outcome had occurred. The HyperRESEARCH software supported the video analysis. The focus of the analysis was to determine if differences in start settings produced different outcomes in speed, ease of use, outcome and design insights.

3.7 Ethical aspects

There are ethical issues to consider during research, and four general requirements for research are the *information requirement*, *the consent requirement*, the *confidentiality requirement*, and the *utilization requirement* (Bryman 2001). Taken together, these requirements are principally directed outwards at informants, while there are also ethical requirements aimed inwards to the researcher. According to the ethical guidelines available at Lund University (Lu 2008), it is possible to divide the ethical guidelines into two categories, *research ethics* and *researchers' ethics*, where the first category is equivalent to Bryman's (2001) four requirements and discussed below. Regarding the latter, *researchers' ethics*, section s 3.1 to 3.6 are related to *researchers' ethics*.

When working with empirical data, Bryman's (2001) recommendations for *research ethics* are manageable and feasible when the information itself is not sensitive or provocative. By informing those involved at an early stage about the purpose of the study and how the information will be presented, the information requirement is satisfied. If the informants disagree, they can decline any participation in the study. The consent requirement overlaps with the information requirement because participation is voluntary and no informants of low age are interviewed. The confidentiality requirement is satisfied by only presenting information about informants with their consent. In those cases where the organisation demands anonymity, the identities of the informants and organisation are obfuscated. The utilization requirement implies that the information collected is used only in the specific investigation, and this is agreed upon with every informant.

From my perspective, the research carried out in this dissertation has not conflicted with the guidelines of *research ethics,* and my belief is that the requirements are fulfilled.

3.8 Contribution in chapter 3

The main contribution in this chapter, compared to the papers, is the improved opportunity for the reader to scrutinise the trustworthiness of the research carried out in the study (see section 5.2.1 for a discussion on trustworthiness). A contribution put forth in three main themes, *pre-knowledge*, *method* and *case presentations*.

The *pre-knowledge* justifies the motivation to apply a design science approach; an approach that guide aim, method and outcome.

The description on *method* should help the reader to judge the quality of the empirical research.

Finally the *case presentations* that offers more thorough descriptions, compared to the papers, on context where the empirical findings are made.

4 Framework, Toolkit and Design Propositions

In this chapter the findings and contributions in form of framework, toolkit and design propositions are presented. Whereas a considerable part of framework and design propositions are presented in papers; in this chapter they merge into the toolkit that is not presented in any of the papers. As shown in figure 32, this section starts with a presentation of the accentuated factors framework of handheld computing.

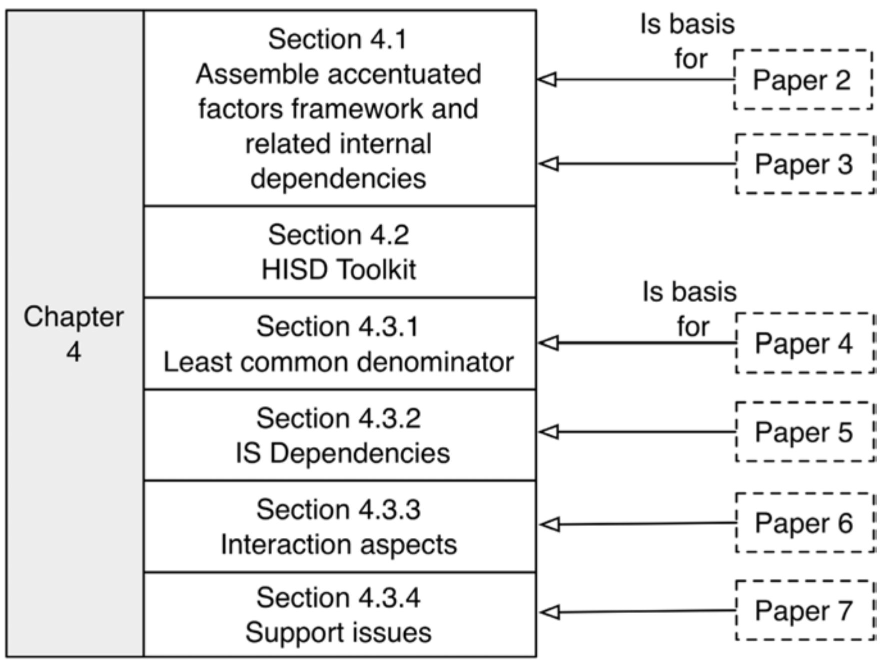

Figure 32. A graphical illustration of this chapter's structure. It describes the order of sections and where the findings of the papers are used in this chapter (the directional arrows).

4.1 The accentuated factors framework

In the three case studies and in the evaluation of the tentative framework, new accentuated factors were found and some existing factors were modified. These factors are presented in papers, but their origin is not explained in detail. Therefore, a more detailed account is presented here.

4.1.1 New factor: Information system dependencies

In the ACME case, a computerised information system and handheld computers replaced a paper-based information system. The users' opinions on this system were studied, although from a developer's perspective, and lessons to be learned from the case were sought.

Early in the work with data collection and early steps of analysis one aspect surfaced, problems occurring due to misalignment between the implemented processes in the handheld information system and the work processes in the work as ambulatory service technician.

The analysis displayed a rigid system with a moderate degree of complexity and, from the users' perspective, an appropriate number of features. There was a variation in direct use based on the judgment of perceived structure as was found to be a consequence of the rigid system and the unpredictable nature of mobile fieldwork:

"*In some cases I buy some cheap accessory, a hose for example, at a gas station. It is almost impossible to insert a spare part or accessory into the inventory stock balance ... if it is not in the inventory stock I cannot bill the customer.*" ST4

"*The customer needs a replacement generator and I may have a spare generator in my truck, however according to the inventory stock balance on the handheld I am out of generators. If that is the case I cannot charge the customer for the generator because it does not exist according to the computer ... correcting this problem is very cumbersome and has to be done at headquarters.*" ST1

"*You are locked into these applications. If there is no support for a given task, don't do it.*" ST2

Another aspect was the unreliable quality of service during synchronisation. The users were instructed to synchronise frequently due to fast updates on invoices and because new service orders and messages to users were distributed via synchronisation and pull:

"*Well, if I do synchronise the unit and the information is lost, what can I do? You can't expect me to write down everything. But I really do like the system and I do not want to go back to paper orders. If you were a bit malicious, you could take a day off and blame the system: no one would be able to check.*" ST3

"*If I cannot synchronise, and that is often the case, I will not receive any service orders and hence have nothing to do.*" ST4

In an email from IT management, service technicians were informed that the latest update of the mobile application would increase the work load on field workers by even more cumbersome information processing, but it was suggested that the field workers should appreciate the update because it reduced the workload for the clerks managing invoices. This implied that the problems with cumbersome and error-prone information handling on the handhelds was known but not yet solved.

The users were also concerned about the information from management that all binders (approximately 30) containing blue prints, service instructions, etc. should be replaced with an application on the handheld:

"*It is nearly impossible to use the handheld for viewing blueprints due to the small screen – and imagine if the application stops working.*" ST3

This may imply the obvious problem with the small screen, however, it also portrays another problem: without the information, the workflow may halt.

In the analysis, one aspect was distilled down: the high reliance on the information system. In the case of ACME, this was due to the design of the mobile information system—the user was highly dependent on the system in order to acquire new service assignments, create waybills, and report the service to headquarters.

In other words, in those cases where the computerised mobile information system is the only information system, the reliance on the information system becomes more critical compared to the ordinary desktop computing system. That is, at a desktop and in an office environment, there are often more opportunities to bypass the system or do other tasks. Thus, this new factor is labelled Information System Dependency.

This factor, or circumstance, is also presented in paper 5 and there accompanied with a design proposition (Andersson and Carlsson 2009).

4.1.2 New factor: Support Issues

In the ASPEA case, the developers worked closely with the end users such as dispatch staff and taxi drivers in the development of the logistic system. One specific aspect stood out in the ASPEA case: support to the outbound user. The developers at ASPEA, with long working experience, had witnessed how the change from mainframe environment to distributed computing power in personal computers had fundamentally changed support issues. Thus, support issues and the relation between appropriate support and overall information system acceptability are well known within personal and desktop computing.

The developers at ASPEA were aware of this and also perceived major differences regarding support to the mobile workforce, compared to the stationary workforce:

"*When you are error tracing, it is often necessary to recreate the situation where the error occurred, something that is often much more complicated because the settings may be impossible to recreate... you cannot for example recreate the field conditions with varying connectivity in a lab environment.*" P.H.

"*You have to design the system in order to manage the problems in recreating the situation where the error occurred.*" R.N.

Another aspect is the extended set of platforms to support, increasing the demands on the support staff to get more and wider knowledge to be able to support this expanding platform:

"*Depending on the installed platform, support staff may suffer the effects of a fragmented environment...data transmitted via different operators, different devices, different settings on devices and even different applications...the complexity increases and the demands on very broad and deep knowledge in different technologies increases rapidly, making the support task very complicated.*" P.H.

The use situation contributed to the complexity of providing appropriate support:

"*As our users are off-task, they cannot halt their main task, driving, when a problem occurs. Instead they contact us after the driving assignment is fulfilled or when they get time...days may pass before an error is reported. And suddenly we have a historical problem to manage.*" P.H.

The results identified an increased complexity compared to desktop computing based on a fragmented technological environment, outbound users, off-task users, and difficulties in fault tracking.

In other words; where the user is outbound and off-task the settings to provide appropriate support are different compared to personal computing. Problems in recreating the situation where the fault occurred are often difficult; furthermore, the prospects for informal knowledge transfer regarding use experience between end users and support is hampered by the geographical distance between co-workers, support staff, and the end user. Hence, this factor should be considered during design and evaluated regarding importance and possible actions to make. This factor is labelled *support situation*.

This factor, or circumstance, is also presented in paper 7 and there accompanied with a design proposition (Andersson 2011).

Regarding this factor, a feature related to the advent of the App market and similar technologies is of interest. When the user is geographically distributed and distant from support staff, aspects such as updating applications or propagating data to a replaced device can be cumbersome. However, today there exists channels via some of the app markets that provides the opportunity to easily notify the user that an update is available. In the case of Research in Motion and their product Blackberry, it is also possible to propagate stored data onto new devices, so for example if a device is lost the user can obtain a new device and very easily restore all their data onto the new device.

4.1.3 New factor: Industry dynamics

In the interviews regarding framework evaluation, the informants put forth their own views on what separates handheld computing from desktop computing. In the first interview, the issue of the high velocity of the mobile industry was raised in the context of the tentative framework:

"In a desktop environment you can develop applications durable for five or ten years...in the mobile environment two year is a lifetime." D.P.

"The development of devices and technologies is so rapid that it is hard to find devices still on the market only after a short time...the fire department in Tomelilla scans the second-hand market for Ericsson R310s—the sharkfin—and buys every available one." D.P.

This new factor was noted and in the subsequent interviews and, if not already mentioned by the informant, it was presented at the end of the interview. Hence, all informants acknowledged the high velocity as a unique property of handheld computing. C.M. at Cybercom opened the interview with the statement:

"The most striking is the grotesque speed of changes... I am baffled over the speed, a speed that seems to increase."

This view is supported by other informants:

"The technologies change very fast, regarding devices...compared to the Windows environment that is very stable" E.W.

"The speed is also dependent on customer demands, only six months after release we had to do a major overhaul because a new version of the operation system allowed new functionality and the customer wanted to benefit from this." H.M.

This considered, high-velocity environment was suggested as an additional factor. It identifies the fast-changing environment with competing vendors, manufacturers, and content providers, and it was argued that this factor is more fierce and withstanding than within desktop computing. Furthermore, the lifecycle of an application is shortened on a handheld device due to the shorter expected lifetime of the device itself, more frequent changes in operating systems (with a low degree of backward compatibility), and faster changes in mobile operator platforms, etc. However, the label high-velocity environment implies a value, so to be consistent with the accentuated factors framework it is relabelled as *industry dynamics*.

4.1.4 Modification of existing factors

In general, the informants agreed upon the presented factors, whereas *field-use conditions*, *small form factor hardware, supporting technologies* and *varying connectivity* were considered appropriate and with informative labels. However with suggestions on relabeling and modification on some factors.

Concerning small *form factor interface*, a roll back to one of B'Far's dimensions was made. That is, *small form factor interface* was divided into *small form factor interface* and *multimodal interfaces,* a separation of concerns. The argument was that the former concerned limitations and the latter extensions:

"*One perspective on your small form factor is that it illustrates both limitations such as the small screen and things that are not present on the desktop...The gyro is an extension not present on the desktop.*" J.P.

The result was a reintroduction of multimodal interfaces into the framework.

It was clarified that the label *task dependencies* were error-prone because in some cases this was a reserved word. It has a specific meaning in programming, which obscured the sought interpretation. For clarity, the label *interaction pattern* was decided on. The same procedure was carried out regarding *time dependencies* and *place dependencies*, where the use of *dependencies* created ambiguity. These were replaced with *time critical* and *place critical*. *Platform proliferation* may be an established term in research and in some specific settings, however I had to explain it every time and realised that platform proliferation could be replaced with the more intuitive *platform variation*. *Security risks* were replaced with the more neutral *security issues*, because not every issue is a risk. Regarding *context awareness*, both place and location awareness can be labelled as context awareness, but this is questionable, as context is more than the place. Place and location are parts of context, but context also includes the surroundings, both physical (such as noise etc.) and social surroundings (Butzs 2004, Schmidt et al. 1999) making context not an appropriate label. As a consequence, this factor is labelled as *location awareness*. Figure 33 is a graphical illustration of the conversion of labels. In the figure the new factors are marked with * if they originate from the case studies and with ** if they originate from interviews.

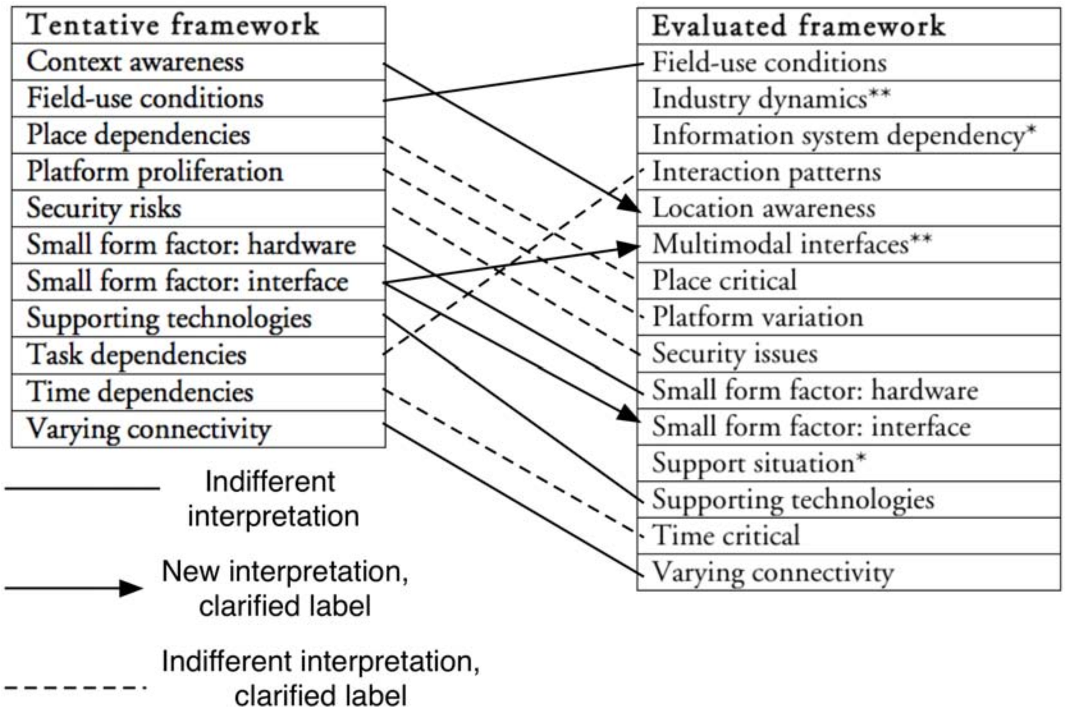

Figure 33. Connections indicate similarities and differences between the tentative framework and the evaluated framework. Factors marked * were identified in case findings and factors marked ** were put forth in the evaluation of the factors. The directional arrows describes a non-reversible change.

The framework in the form of a collection of individual factors can be considered as a theory for describing the nature of handheld computing for the mobile workforce from a designer's perspective. Hence, the accentuated framework is an example of a theory for analysing and describing according to Gregor (2006): "The theory does not extend beyond analysis and description. No causal relationships among phenomena are specified and no predictions are made." (Gregor 2006, p. 620).

The primary use is in early design and analytical evaluation of proposed handheld information systems developed for the mobile workforce with users as digital rangers.

Below is the finalised version of the comprehensive, evaluated framework presented (see table 21). This framework is also presented in paper 2 (Andersson and Henningsson 2011).

Table 21. The final set of accentuated factors—the accentuated factors framework. Each factor has a block letter that is used in forthcoming HISD Toolkit Cards.

Factor	Short description
Field-use conditions (A)	The field-use conditions are most likely in the form of a lack of predefined workspace. Larger variety in surroundings, such as quiet or noisy environments, sunlight, darkness, heat, or low temperature, affect how a user can interact with the device.
Industry dynamics (B)	The lifetime of an application, a platform, or a device is shorter and the standards and specifications change more often, compared to stationary computing.
Information system dependencies (C)	In those cases where the mobile IS is the only IS, the reliance on the IS is more critical, compared to desktop computing. If the IS malfunctions, the desktop user may have more opportunities than the mobile user to proceed with other tasks or bypass the IS with other applications.
Interaction patterns (D)	Interaction patterns deal with the notion of a user occupied with tasks other than information handling. An effect of this is that the user's attention is directed away from the computing device. Information management is not the core process for the mobile user; it is merely a support process. A use pattern related to this is short interaction cycles when performing computing tasks—the user does not plan for hour-long sessions. This may require shorter interaction patterns.
Location awareness (E)	This is the device's ability to know its actual geographical location in real time.
Multimodal interfaces (F)	Handheld devices usually have more input and output interfaces, such as audio, camera, gyro, GPS, and LDR.

Place critical (G)	Most common is the notion of freedom of place, however here an enhancement of 'anywhere', separating voluntary and mandatory use, is made. For the mobile workforce "just in place" is more appropriate.
Platform variation (H)	This denote variation in software and hardware platforms and a large set of stakeholders.
Security issues (I)	Security issues are two-fold: security threats concerning wireless transmission and increased risk of a device being lost due to small form factor and omnipresence.
Small form factor hardware (J)	Due to miniaturization, the hardware performance and capabilities may be limited. Memory, power supply, and processing capacity are examples of this factor.
Small form factor interface (K)	Due to miniaturization, the physical interfaces are different compared to desktop computing.
Support situation (L)	For the geographically distributed workforce, the possibilities for support can be limited due to the physical distance.
Supporting technologies (M)	There is a lack of supporting technologies such as books, manuals, fax machines, copiers, printers etc.
Time critical (N)	Most common is the notion of freedom of time, however here an enhancement of 'anytime' distinguishes voluntary from mandatory use. For the mobile workforce "just on time" is more appropriate.
Varying connectivity (O)	This relates to variation in transmission rate and variation in connectivity.

When elaborating on a set of factors such as these, one must be aware of dependencies between factors making them paradoxical or wicked problems (Rittel and Webber 1973). They can influence each other in enforcing or disruptive ways. For example, unreliable wireless connectivity could be managed by designing autonomous applications with low reliance on the network and storing the data on the device. However, this can be problematic due to memory limitations. Furthermore, the assumed problems with processing capacity make it attractive to outsource as much as possible processor-consuming calculations on external servers, but this can be jeopardised by unreliable wireless connectivity.

A device that is small and easy to carry is likely to be ever-present and, as a corollary, at an increased risk of being stolen, which affects how sensitive data are treated. One strategy to protect sensitive data is by enforcing high security levels such as password protection and encryption, but this is contradictory to the demand for fast interaction patterns. To avoid slow interaction, sensitive data could be stored on servers; however, this can be jeopardised by unreliable wireless connectivity. Hence, instances of wicked problems or dilemmas can emerge without an optimal solution. As a consequence, each factor cannot be independently optimised instead all relevant factors must be considered together.

Despite wicked problems, the framework of accentuated factors is applicable as an analytical tool in research on handheld computing, as a design tool, and as an analytical tool in the outlining of handheld information systems, according to the informants. It would assure that no important factors are overlooked. Which factor is most important depends on the context and must be analysed from the case settings at hand. It can guide explanations on successful implementations as well as failures. Furthermore, it can be applied as an analytical tool in evaluation of existing systems:

"*A framework as such can be valuable in benchmarking competing proposed systems in procurement of a mobile information system.*" D.P.

"*This framework would be useful for anyone procuring a mobile IS, assisting that person to evaluate if all, for that specific case, important factors are recognised.*" D.P.

Furthermore:

"*Useful framework to specify the important factors in design, and also to evaluate an existing system and see if it matches the needs.*" G.F.

In the first nine interviews, the informants were asked *Who could be a potential reader or user of a framework as such*, and the answers tended towards someone dealing with concepts rather than code, as the quotes above also imply.

"*Based on my experience, this is most usable for the program owner or the architect...not the developer because they are more concerned with details and this is an overview.*" J.P.

"*The programmers are not allowed to make decisions like these, the decisions are already made at a higher level in the organisations.*" C.O.

Furthermore, regarding the level of sophistication, it was suggested that a more general or abstract level was preferable:

"*You should not explain that a specific tool should be used, or that a specific algorithm should be used. The programmer already knows that, what's needed are descriptions on a more general level to understand how the pieces fit together.*" M.S.

Not only the architect or designer but also the customer was considered as a potential reader because:

"*This would be very useful for most people in procurement. We put tremendous efforts in explaining mobile technologies for our customers because they have very little knowledge on mobile computing.*" M.A.

4.1.5 Dependencies between accentuated factors

The proposed framework in the previous section is an example of a theory for analysing and describing (Gregor 2006). In order to develop the framework further, the dependencies between the factors in the framework are described and the framework is developed into an early (somewhat immature) version of an explaining and predicting (EP) theory according to Gregor's taxonomy: "Says what is, how, why, when, where, and what will be. Provides predictions and has both testable propositions and causal explanations" (Gregor 2006, p. 620). See table 22 for an aggregated summary of identified dependencies. This extended framework with dependencies is also presented in paper 3 (Andersson 2012a)

Table 22. Dependencies between factors identified in empirical data. The abbreviations (for example *FieU*) are used in forthcoming figures 34 and 35. Each group of dependencies are accompanied with an excerpt from the interviews or from which case there are derived.

Depending factor	Dependent factor	Number of dep.
Field-use conditions (FieU)	Small form factor interface (SmfI)	3
"the service technicians are forced to do service on machinery in very small and dark machine rooms, you cannot demand that they should fiddle with a stylus on a touch screen under those circumstances" Informant I		
Field-use conditions (FieU)	IS dependencies (IsdP)	1
"these problems increase when you are truly mobile, you cannot write additional information on paper – I do not even have a pencil with me anymore" Informant O		
Field-use conditions (FieU)	Security issues (SecI)	2
"there is an explicit risk doing bank errands on a bus – anyone behind you may intercept" Informant A		
Field-use conditions (FieU)	Interaction patterns (IntP)	6
"you are pacing to the tube—here is the context again—pick up your phone,		

unlock your phone, start the ticket-app, then swipe it – too many steps!" Informant A		
Field-use conditions (FieU)	Small form factor hardware (SmfH)	6
"the users are driving to the customer and often need to take a quick glance at the screen during driving, therefore the device became a netbook with a considerably larger screen" Informant M		
Industry dynamics (IndD)	Interaction patterns (IntP)	1
"the industry and profession is so immature and changes so fast and how to use an application is outdated so quickly nowadays" Informant O		
Industry dynamics (IndD)	Small form factor hardware (SmfH)	2
"the application cannot outlive the hardware, and the hardware will be replaced every 24 months" Informant J		
Industry dynamics (IndD)	Support situation (SupS)	1
Derived from the 21st case		
Industry dynamics (IndD)	Platform variation (PlaV)	1
Derived from the 21st case		
IS dependencies (IsdP)	Support situation (SupS)	1
"the mission critical ERPs must have support, prepared and on standby all the time. And you must have a plan when things go out of control" Informant G		
IS Dependencies (IsdP)	Varying connectivity (VarC)	4
"the information is stored onto the handheld and he synchronies when he returns to home—it is critical that it works even in off-line mode" Informant A		
Interaction patterns (IntP)	Support situation (SupS)	4
"they do not, and will never, read manuals, you have to design a workflow so easy that they never need support, and it is possible, keep it simple" Informant J		
Multimodal interfaces (MultI)	Support situation (SupS)	1
"you just shake the device to reload information, however, there is no information about this procedure at all. You have to learn this, and it can be problematic in some cases" Informant O		
Multimodal interfaces (MultI)	Interaction patterns (IntP)	2
"location awareness and GPS can speed things up, you let the device fill in the place based on geo-data" Informant L		
Multimodal interfaces (MultI)	Small form factor interface (SmfI)	1
"we use the bar code scanner to relieve the user from cumbersome input, it is easier this way" Informant N		
Multimodal interfaces (MultI)	Location Awareness (E)	1

"GPS is not necessary to find a location, NFC and known places for the senders are enough to localize the user" Informant N		
Multimodal interfaces (MultI)	Supporting technologies (SupT)	1
"the customers have to sign, in the previous system they had printers in the trucks but they are removed now, the customer signs on the handheld screen" Informant M		
Place critical (PlaC)	Small form factor hardware (SmfH)	1
"do you really need data right here, cannot you move outside, and how much data can we store on the device, do you really need all that data—these are questions we must ask the users" Informant A		
Place critical (PlaC)	Varying connectivity (VarC)	1
Derived from the ACME case		
Place critical (PlaC)	IS Dependencies (IsdP)	1
Derived from the ASPEA case		
Place critical (PlaC)	Time critical	1
Derived from the ACME case		
Platform variation (PlaV)	Industry dynamics (IndD)	1
" a hot industry, the more entrants into the industry the pace will increase, we have experience of that already" Informant A		
Platform variation (PlaV)	Small form factor hardware (SmfH)	2
"in the logistic system, we demanded what device they could use, the MC75 was the only one approved by us" Informant M		
Platform variation (PlaV)	Small form factor interface (SmfI)	3
"and the SE-Mini is a catastrophe, and the Android comes and makes it even worse with all their different screen sizes" Informant J		
Platform variation (PlaV)	Support situation (SupS)	1
"in those case where the users may choose devices by themselves, they will choose devices of their liking and most likely will not complain – less support" Informant J		
Platform variation (PlaV)	Interaction patterns (IntP)	2
"you must be stringent concerning logic in the application, however different devices' operating systems have different logic making it almost impossible to manage this" Informant B		
Small form factor hardware (SmfH)	Field-use conditions (FieU)	1
"as the manager at SkiStar said - neat to have but does it function in below −20		

degree Celsius?" Informant E		
Small form factor hardware (SmfH)	Platform variation (PlaV)	2
"Some devices have the ability to conform to or at least tweak the application by themselves so it fits the hardware" Informant B		
Small form factor hardware (SmfH)	Varying connectivity (VarC)	2
"nowadays you got several connection techniques, GSM, 3G, 4G, WiFi, Bluetooth—this reduces the risk of being disconnected" Informant J		
Small form factor hardware (SmfH)	Security issues (SecI)	2
"it‘s easy to protect information in the device from other applications on the device, although on the better OS" Informant B		
Small form factor hardware (SmfH)	Location awareness (LocA)	1
Derived from the ASPEA case		
Small form factor hardware (SmfH)	Small form factor interface (SmfI)	5
"as a hardware manufacturer you often ship your device with your own skin, changing whatever the OS intended" Informant F		
Small form factor interface (SmfI)	Interaction patterns (IntP)	6
"you must be able to manage it with one hand, and you cannot, ever, use drop downs and long lists, it must be usable directly" Informant P		
Small form factor interface (SmfI)	Platform variation (PlaV)	1
Derived from the 21st case		
Supporting technologies (SupT)	Field-use conditions (FieU)	1
"if supplied with a printer, for example, the truly mobile user will be even more free, that is, able to use the technology anywhere" Informant F		
Time critical (TimC)	Place critical (PlaC)	2
"and as a consequence – it is obvious if you need information always you will need it everywhere" Informant M		
Time critical (TimC)	IS Dependencies (IsdP)	1
Derived from the ACME case		
Time critical (TimC)	Small form factor hardware (SmfH)	1
"and, do you really need real time data, do you really need all that data right now—these are questions we must ask the users" Informant A		
Location awareness (LocA)	Interaction patterns (IntP)	1

Derived from the ASPEA case		
Varying connectivity (VarC)	Small form factor hardware (SmfH)	6
"in those cases we propose interim storage in the device, if the device can handle it, then the user can use it regardless of connectivity" Informant D		
Varying connectivity (VarC)	IS Dependencies (IsdP)	6
"the taxi driver driving in the countryside, the client wanting to pay with credit card—and no connectivity" Informant J		
Varying connectivity (VarC)	Industry dynamics	1
Derived from the 21st case		
Varying connectivity (VarC)	Support situation (SupS)	1
"if the handheld is lost and replaced with a new one, the time to push, via the cloud, all programs and settings are much faster and easier on a handheld than a desktop, you are up and running in a couple of hours - try that on the desktop" Informant A		
Varying connectivity (VarC)	Interaction patterns (IntP)	3
"some data are stored on the device, some are downloaded – the more to download – the slower to get working" Informant F		
Varying connectivity (VarC)	Security issues (SecI)	3
"if downloading data about a patient, it is crucial that no one can intercept the traffic" Informant M		

With the aim of increasing the readability of the data, a diagram was constructed to visualize the factors and their dependencies; the arrows display the direction of influence (see figure 34).

The data, presented in table format (table 22) and in the diagram (figure 34), display an uneven distribution of dependencies. A conclusion is that these differences point to appropriate departures for a designer or developer embarking on a new project; starting the design process by making design considerations on a low importance factor increases the likelihood of being forced to revise these design considerations later on. The recommendation put forth is to start with the high important factors because they will affect the low important factors, and not vice versa. It is important to recognise the contextual nature of the dependencies, and these must be analysed from the actual case settings at hand. However, the identified dependencies and their magnitude are indications of where to begin the analysis.

The dependencies support designers and other stakeholders in navigating the complex environment of handheld computing.

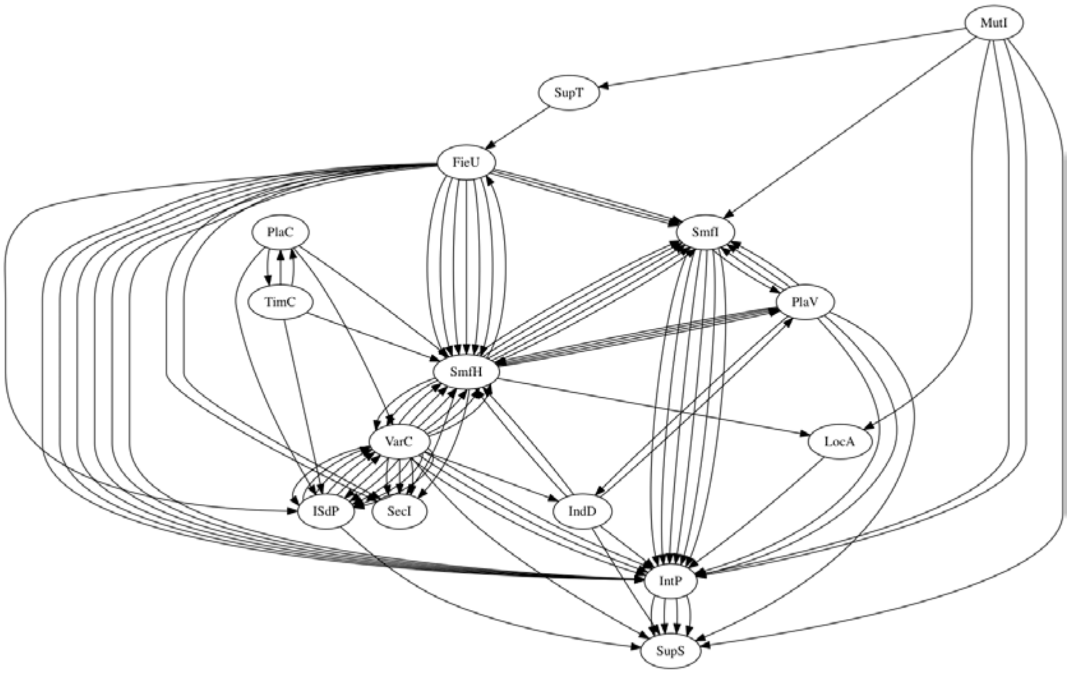

Figure 34. All dependencies illustrated via Graphvis network diagram software. The abbreviations used in the diagram corresponds to table 22, the directional arrows describes which factor are dependent or depending. Abbreviations are used in the figure, see table 22 for the conversion.

Being comprehensive, the illustration in figure 34 may be complex to interpret. With the ambition to focusing on the most influential factors the data were filtered using SCCMAP (North and Gansner 2001). From this, a diagram is constructed where the neighbours with low influence are reduced and removed from the diagram. The arrows in the diagram display the direction of influence. Due to this reduction the number of dependencies in table 22 and figure 35 are not equivalent. However, a note of precaution whereas the dependencies are not casual laws, instead they should be considered as likely dependencies and aspects to investigate between the designers and customers. The reduced diagram portrays the seven most influential factors (see figure 35).

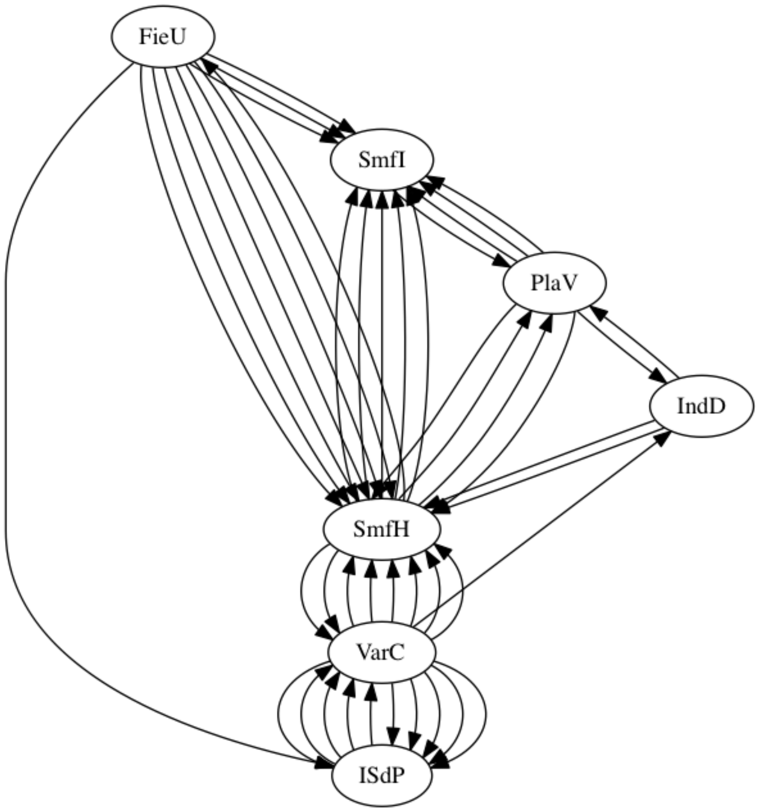

Figure 35. Reduced set of dependencies between factors in the accentuated factors framework. Diagram created with Graphvis network diagram software and SCCMAP filter. Directed arrows describe the internal dependencies between factors. However, there is no distinction made between supportive and disruptive dependencies. In this diagram the less influencing factors, that is, the distant neighbours are removed and only the core factors from data in table 22 is visible. Abbreviations are used in the figure, see table 22 for the conversion.

4.2 The HISD Toolkit

A part of this dissertation's aim is to develop a toolkit derived from the comprehensive accentuated factors framework, i.e., to present the framework in a version applicable for practitioners. Hence, the informants in the first nine interviews were asked *how should the framework be presented/illustrated/displayed to a potential reader*?

The suggestions varied from a textbook written in Swedish to YouTube clips. Although with some variation, the analysis expressed agreement among the informants regarding some basic properties—the framework factors should include an *understandable title*, *a short explanation*, and *some high-level examples*. The perceived use often involved some collaborative environment, for example discussions between program owners and customers, or workshops with architects and developers:

"*We put tremendous efforts into explaining mobile technologies to our customers because they have very little knowledge of mobile computing.*" M.A.

One of the informants had used a similar framework in another domain and proposed a solution that caught my attention:

"*You should really look at UXBASIS (Uxbasis 2011), they have built a tool for analysis of business intelligence and development.* " C.Ö.

UXBASIS is a toolkit where a set of cards is used to communicate with stakeholders in development projects. The cards resemble Scrum cards, but they have a fixed content.

With the aspiration to design a toolkit supportive of collaboration, concepts from agile methods were considered. "Agile development methods...emphasise close collaboration, co-ordination and communication within the development team" (Robinson and Sharp 2010 p. 49). A collaborative tool used in agile methods such as Scrum is the task board, or the Scrum wall, where stakeholders and members of a project can discuss and organise tasks and keep track of a project's progression, see for example Robinson and Sharp (2010), Schwaber and Beedle (2002), Sharp and Robinson (2010) (see figure 36 for illustrations of a Scrum wall).

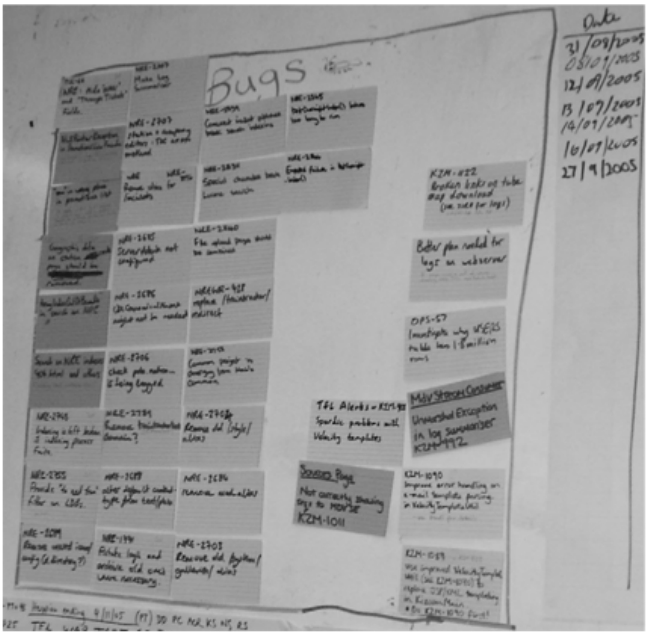

Figure 36. Scrum cards arranged on a Scrum task board (Sharp and Robinson 2010 p, 74). The cards are easily rearranged and it is possible to record the cards with photos to capture the actual status.

The proposed toolkit in this dissertation, the *Handheld Information System Design Toolkit* (HISD Toolkit) builds on agile methods, where the accentuated factors resemble Scrum cards and are applied in a method similar to the Scrum wall method. Furthermore, the toolkit is inspired of the UXbasis method.

A card represents a factor, and each card contains the label, a short introduction, and an demonstration example of the factor. Each card has a block letter that corresponds to the diagram used in the manual (see figure 37 for an example of a card).

Although the factors are individual, they may depend on each other, as reflected upon in section 4.1.5. Based on empirical findings (presented in section 4.1.5 and in paper 3 (Andersson 2012a)), dependencies between the accentuated factors are identified, suggesting that some factors are of greater importance than others.

The practical implication of these findings is that in the design phase of handheld information systems the initial focus should be on the most important and influential factors in order to reduce the risk of extensive revision of design further on in the project. In other words, starting optimization by managing less important factors is most likely a waste of resources because the more important factors may necessitate changes later on.

The proposed use of the HISD Cards is to discuss each factors importance and relation to other factors, based on an actual case. This is preferably carried out in a workshop setting and the cards arranged on a whiteboard or equivalent. Based on the discussion during the workshop a network diagram should be constructed on the whiteboard, distilling the most important factors to manage in the specific case.

Hence, the most important factors should be considered, or optimised, first in forthcoming requirements specification.

B	**Industry dynamics**
This illustrates that hardware, software, and ancillary systems are changing rapidly and that it can be difficult to design applications that are functional for longer time periods. Examples are the expected short turnaround time for both operating systems and handheld devices. This also illustrates the fast-changing environment with competing vendors, manufacturers, and content providers, and it is argued that this factor is more fierce and withstanding compared to within stationary computing. The lifecycle of an application is shortened for a handheld device due to the shorter expected lifetime of the device itself, with more frequent changes in operating system versions (with a low degree of backward compatibility) and faster changes in carriers, platforms, etc.	

Figure 37. Sample of a HISD Card, the *Industry dynamics* HISD card. It is marked with the letter B, which corresponds to instructions in the manual and to table 21.

4.2.1 Modifications based on evaluation

Regarding the evaluation of the toolkit, the aim was to investigate if different versions of the initial settings influenced *outcome*, *ease of use* and *speed*.

In figure 35 a reduced set of dependencies was illustrated (see section 4.1.5). Motivated by these dependencies and the argument to start with the most important factors, the start arrangement according to this diagram would be a natural start. Hence, being the independent variable in the experiment. See appendix 7.8 for detailed instructions in the first round of experiments. In the first round of experiments the start settings were as illustrated in figure 27 and appendix 7.8.

In the analysis of photos and field notes no differences in *outcome* between the three groups was discernible, and the conclusion was that the case description influenced the users more than the initial settings of factors on the whiteboard. Interesting was that the three groups developed rather similar models, independently.

Regarding *ease of use,* one thing seemed to be similar between the groups. When analysing the data I realised that rearrangements due to varying interpretations and judgement on factors' importance were cumbersome. The users had to rewrite the diagram when the degree of importance of a factor was changed during discussion.

Regarding *speed*, suggesting uncomplicated start arrangements caused a slower start. However, suggesting complicated start arrangements instigated more rearrangement of factors during the workshop.

With the aim of enhancing the HISD Toolkit, the following improvement was made based on analysis of the first round of experiments.

The proposed initial setting become the three most influential factors *field-use conditions, small form factor hardware* and *varying connectivity* (marked A, J, and O in the framework in table 21) in order to kick-start a workshop.

It was a deliberate choice not to suggest start arrangement accordingly to figure 35 (section 4.1.5) due to the probability of time-consuming rearrangements of factors. The argument to select *field-use conditions, small form factor hardware* and *varying connectivity* is because they stand out as being the most important factors of all factors.

The next round of experiments confirmed the finding in the first round of experiments, and after analysing all six experiments another improvement were made in order to reducing cumbersome rearrangement of cards.

The cards were further developed from plain cards to cards with an inserted and foldable flag displaying if the factor has *normal importance*, is *nonimportant*, or has *critical importance* whereby reducing the need for rearrangement when revising factors' importance (see figures 38 and 39).

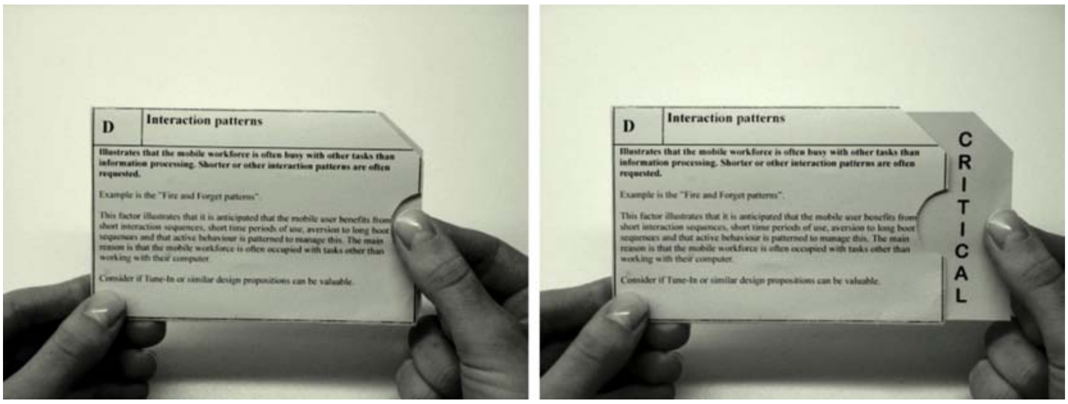

Figure 38. Improved HISD card with a foldable flag. This picture shows the folding out of the “critical” flag.

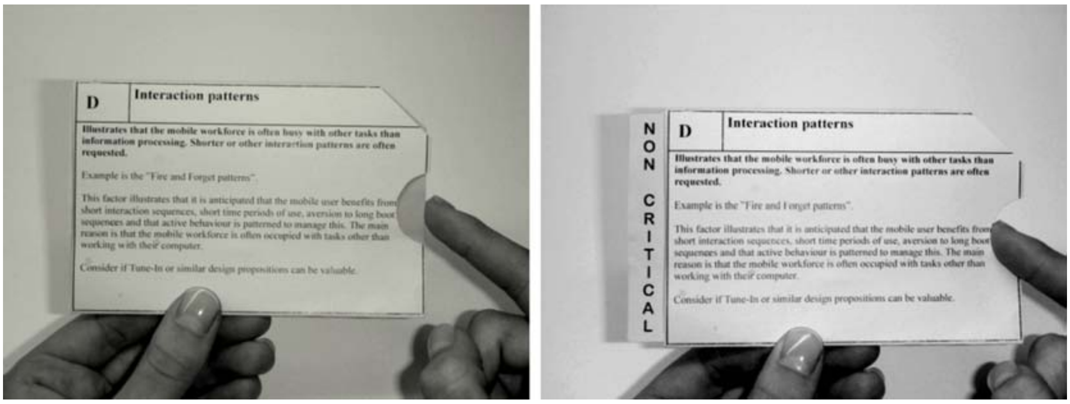

Figure 39. Improved HISD card with a foldable flag. This picture shows the folding out of the “non-critical” flag.

4.2.2 HISD Toolkit parts and process

The toolkit is packaged in a small box with cards describing the accentuated factors, accompanied by instructions for using the cards and background information (see figure 40). The three factors *field-use conditions, small form factor hardware*, and *varying connectivity* constitute the initial settings of the cards on the whiteboard (or equivalent), see figure 41 for initial start arrangement of cards. The proposed process for constructing the diagram is put forth in table 23 below.

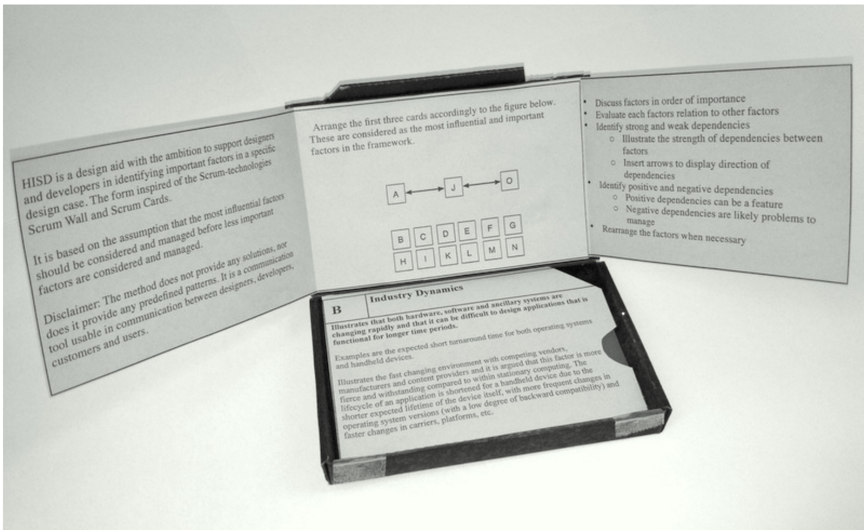

Figure 40. The finalised HISD Toolkit card box containing updated instructions inside the top lid and the enhanced, foldable HISD cards.

Table 23. The proposed workflow for using the HISD Toolkit in the design of a handheld information system

Phase	Main activity	Comments
1	Arrange the factors according to figure 41.	Ensures that the most important factors are managed from the start.
2	Discuss factors in order of importance.	The perspective must be the actual case. Some factors will most likely be more important than other factors.
3	Evaluate each factor's relation to other factors.	The perspective must be the actual case.
4	Identify strong and weak dependencies.	Identifies the strength of dependencies between factors. Insert arrows to display the direction of dependencies.
5	Refine the now existing diagram.	
6	Identify positive and negative dependencies.	Positive dependencies can be a feature. Negative dependencies are likely problems to manage.
7	Rearrange the factors when necessary.	
8	Irrelevant factors should be	

	excluded from the diagram.	
9	Refine the diagram by redoing steps 2–9 until saturation is achieved.	
10	Start the work with the requirement specifications	

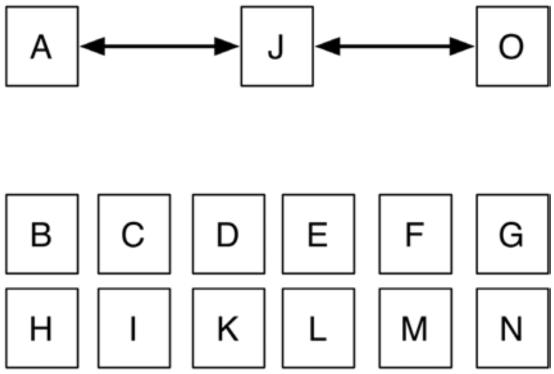

Figure 41. The suggested starting point when discussing factors' importance and design considerations in early design and requirements engineering. The labels in the framework are replaced with block letters in order to increase readability in the small icons. The block letters correspond to the accentuated factors framework in table 21.

Finally, the HISD Toolkit as an aid for collaborative communication, evaluation, and analysis is mapped onto the framework of Gregor & Jones (2007) in order to visualise the constituents of the design proposition (see table 24).

Table 24. The HISD Toolkit mapped onto the Gregor & Jones (2007) framework for design propositions

Component	Description
Core Components	
Purpose and scope	The proposal is a toolkit usable as a collaborative tool in early design and evaluation of proposed or existing handheld information systems for the mobile workforce.
Constructs	Digital rangers, handheld computers, mobile

	workforce, accentuated factors cards, internal dependencies between factors, handheld information systems, and collaborative environment
Principle of form and function	A toolkit based on the accentuated factors framework of handheld computing supporting designers and stakeholders in collaboration to analyse a specific case and to make design considerations in a timely manner, avoiding the risk of redesign later in the process.
Artefact mutability	The method is independent of realising technologies as well as the accentuated factors framework. The toolkit and proposed workflow are easily updated if changes are required.
Testable propositions	To visualise and cooperate on design considerations in early design and to estimate the most important factors, use HISD Toolkit.
Justificatory knowledge	The HISD Toolkit is based on agile system development methods such as Scrum, and based on the accentuated factors framework. The accentuated factors framework is based on theoretical and empirical studies of the properties of the mobile workforce and handheld technologies, such as the property of being a digital ranger.
Additional components	
Principles of implementation	Instruction on how to use the toolkit is enclosed.
Expository instantiation	A physical instantiation of the proposal is developed. The proposed toolkit is suitable for teaching, training, and evaluation.

4.3 Design propositions to manage individual factors

Regarding individual factors, in the literature review presented in paper 1, it was shown that some factors were less researched, for example, *platform variation* and *interaction patterns.* The new factors *support issues* and *information systems dependencies* are self-evident not well illuminated by research. To close these knowledge gaps and to fill in the blanks in the toolkit, design propositions such as *Least common* *denominator*, *Flexible forms*, *Tune-in*, and *Defensive design* are put forward.

These design propositions are all presented in papers (papers 4, 5, 6, and 7); hence only short presentations are made in the following sections. However, the mapping onto the Gregor & Jones (2007) framework has been improved.

4.3.1 Least common denominator

One accentuated factor present in the set of factors was confirmed during empirical studies, *platform variation*. In this section, the design proposition developed from the 21st Century Mobile Solutions case is presented.

Findings revealed that global and national standards for sending multimedia messages are not always truly standardized. It was discovered that operators and mobile phone manufacturers make minor alterations and interpretations of the standards, thereby losing the benefits of the standards. In order to manage these differences, a *Least common denominator* design proposal is put forth.

The design proposition, presented in paper 4, is mapped onto the Gregor & Jones (2007) framework (see table 25).

Table 25. The design proposition of Least common denominator is presented and mapped onto the Gregor & Jones framework.

Theory Components	Description
Core Components	
Purpose and scope	The aim of the design proposition is to develop a system with functionality to reduce problems originating from platform variation.
Constructs	Heterogenic set of devices, heterogenic set of carrier implementations, middleware solutions
Principles of form and function	A server system offering communication between end user computers and mobile phones. In order to manage several carriers, varying implementations of SMSMC, MM7 design considerations must be made.
Artefact mutability	This design proposition is applicable in a variety of settings where there is lack of standards. The proposal is a meta-proposition and is both general and independent of realising technologies. However, all changes in connected systems will interfere and may cause reengineering.

Testable propositions	Applying least common denominator will reduce problems with platform variation, however at a cost of functionality.
Justificatory knowledge	The design proposition is based on a grounded approach and empirically based findings.
Additional Components	
Principles of implementation	Server solutions should be parameter-driven to a greater extent than traditionally applied to manage the rapid changes and the continuous improvements in platforms by stakeholders.
Expository instantiations	A commercial and running system is built based on this proposal.

4.3.2 Flexible forms

A new accentuated factor was identified during empirical studies, *information systems dependency*. In this section, a design proposition to manage the information system dependency based on the ACME case is suggested.

Being a digital ranger—a truly mobile member of the mobile workforce—raises issues such as increased reliance, or information system dependency, on a single application or a limited set of applications. When the application does not support a given task, the disruption can be more critical than in an equivalent desktop information system. To deal with this information systems dependency, a design proposition is put forth, making the information flow more flexible. This will allow the user to choose an alternative path when needed, instead of halting the workflow.

The design proposition, *Flexible forms*, presented in paper 5, is mapped onto the Gregor & Jones (2007) framework (see table 26).

Table 26. The design proposition of Flexible form is presented and mapped onto the Gregor & Jones framework.

Theory Components	**Description**
Core Components	
Purpose and scope	The design proposal's aim is to help designers manage information systems dependency that the mobile user is often confronted with.

Constructs	Digital rangers, information systems dependency, handheld devices, mobile ERP system
Principles of form and function	With the use of flexible forms, the information systems dependency is reduced by the opportunity to bypass the proposed workflow if information is lacking.
Artefact mutability	This design proposition is transferable to most information handling systems. There are possible obstacles to implementing flexible forms in the ERP interfaces; however, this can be solved by using some form of middleware.
Testable propositions	If the use environment is unpredictable and varying, flexible forms are a strategy to reduce rigidity in handheld information systems. As a result, information systems dependency is reduced.
Justificatory knowledge	The underlying perspectives stem from design science and empirical studies of the properties of the mobile workforce, such as information system dependency.
Additional Components	
Principles of implementation	The system should include bypass options to ensure that an information handling process is not interrupted by circumstances outside the user's control.
Expository instantiations	Examples of flexible forms in the form of screen dummies are displayed. These dummies are discussed with end-users and perceived as an enhancement compared to existing systems.

4.3.3 Tune-In

The accentuated factor *interaction patterns* were confirmed during empirical studies. In this section, a design proposition developed from the ASPEA case is suggested that deals with interaction patterns.

A considerable part of the mobile workforce—drivers, maintenance staff, healthcare staff etc.—is chiefly performing tasks other than interacting with their computers. As a result, they are not able to pay attention to computer interaction, making them mainly off computer tasks. Tune-In is a design proposition to manage off-task situations based on the ASPEA case, relieving the user from routine administrative tasks.

The design proposition *Tune-In* presented in paper 6, is mapped onto the Gregor & Jones (2007) framework (see table 27).

Table 27. The design proposition *Tune-In* is mapped onto the Gregor & Jones framework.

Theory Components	Description
Core Components	
Purpose and scope	The aim of the design proposition is to suggest a system with functionality to manage the off-task property of the mobile workforce in the form of transport personnel.
Constructs	Mobile workforce, off-task users, location awareness, active behaviour of a mobile information system
Principles of form and function	By automating routine sign-on and sign-off regarding transport assignments, the off-task property is managed. By using GPS combined with map data and driving assignment information, the drivers are guided via driving instructions and the sign-on and sign-off are completely automated.
Artefact mutability	The proposed solution is not limited to healthcare transportation; it is applicable in most logistic systems, However, if the realising technologies are replaced, the system has to be modified to match new hardware specifications.
Testable propositions	If you want relieve the mobile workforce from routine information handling tasks and to stay focused on the main task, then implement Tune-In solutions.
Justificatory knowledge	The underlying perspectives stem from design science and empirical studies of the properties of the mobile workforce, such as active behaviour, off-task and location awareness.
Additional Components	
Principles of implementation	The proposed solution has been incrementally implemented during the development phase in close relation to the users.
Expository instantiations	The WinHast system is an implemented and fully running system where Tune-In is applied. The features of the implemented design proposition are easily demonstrated via the implemented system.

4.3.4 Defensive design

A new accentuated factor was identified during empirical studies, *support situation.* Below is a design proposition to manage *support situation*, developed from the ASPEA case.

The recent years of development in mobile computing have created opportunities for user-groups that may be more or less geographically distributed to use computerised information system. As a consequence of the geographical distribution, more or less marooned when it comes to receiving IS/IT support. A design proposition reducing the need for support, *Defensive design*, based on the ASPE case is presented.

The design proposition, presented in paper 7, is mapped onto the Gregor & Jones (2007) framework (see table 28).

Table 28. The design proposition of Defensive design is presented and mapped onto the Gregor & Jones framework.

Component	Description
Core Components	
Purpose and scope	The aim of the proposition is to develop a system with functionality to reduce the need for support to the geographically distributed mobile workforce such as transportation personnel.
Constructs	Digital rangers, defensive design, mobile workforce, handheld computing devices, outbound users
Principles of form and function	Reducing the need for support by means of remote management of handheld devices and by automated recovery functions and automated failure protection schemes
Artefact mutability	The proposed solution is not bound to logistic systems; it will be possible to transfer the proposed solution to other systems with outbound users. However, if the realising technologies are replaced, the system has to be modified to match new hardware specifications.
Testable propositions	If you want limit the problems originating from the geographical distance between remote users and support staff, then implement defensive design in the information system and the handheld computing devices.
Justificatory knowledge	The underlying perspectives stem from design science and empirical studies of the properties of the mobile workforce, such as the property of being a digital

	ranger.
Additional Components	
Principles of implementation	The proposed solution has been implemented incrementally during the development phase in close relation to the users.
Expository instantiations	The WinHast system is an implemented and fully running system where defensive design is applied. The features of the implemented design proposition are easily demonstrated via log files and historical data.

4.4 Contribution in chapter 4

The aim of this dissertation is to address the lack of a comprehensive approach by developing a comprehensive framework and a toolkit derived from the comprehensive framework.

The main contribution from this chapter is undoubtedly *a comprehensive framework of accentuated factors of handheld computing* and a *toolkit derived from the accentuated factors framework*.

Furthermore, design propositions managing less researched factors and thereby complementing the toolkit are also put forth.

These contributions can be arranged in three main parts whereas the accentuated factors framework is one part; the design propositions are presented in papers is another part; the toolkit being presented in the cover is the final part. Hence, the cover is not only an overarching argumentation for the papers, it does contain a contribution: in the cover the two former parts merge into the latter (see figure 42).

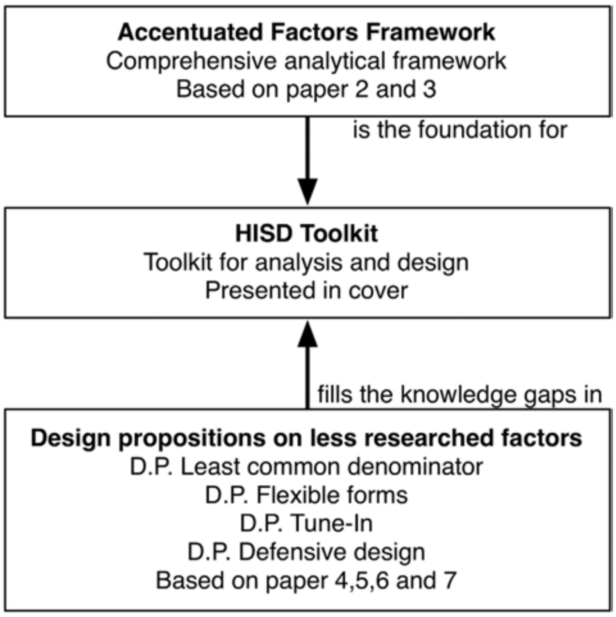

Figure 42. This figure describes how the main contributions are combined. The accentuated factors framework is the theoretical foundation of the HISD Toolkit; meanwhile the design propositions complement the HISD Toolkit by providing suggestions how to manage specific, less researched factors. The arrows are directional and describes that the relations between the main contributions are not reversible.

5 Research contributions and conclusions

In this final chapter, a discussion on contributions is presented. It includes the research contributions as well as reflections on the quality of the research. Furthermore, it discusses avenues for future research and finally, concluding remarks are made.

5.1 Knowledge contribution

The aim of this dissertation is to address the lack of a comprehensive approach to the design of handheld information systems for the mobile workforce by developing a *comprehensive framework* and a *toolkit* derived from this framework.

Hence, the main knowledge contribution of this dissertation is the *accentuated factors framework* and the *HISD Toolkit*. Furthermore, in order to close knowledge gaps related to the toolkit, *four design propositions* are put forward, which are considered as part of the main contribution. *Additional contributions* are revised concepts of handheld computing and the application of design science approaches.

Concerning the *accentuated factors framework,* the contribution in the form of a set of individual factors belongs to the category of analysing and describing theory. The improved accentuated factors framework displaying the dependencies between the factors is a contribution belonging to the category of explaining and predicting theory. Furthermore, both versions of the comprehensive framework is examples of abstract artefacts (Gregor 2006, Gregor and Jones 2007). The theoretical implications are that the accentuated factors framework adds to the existing knowledge base on handheld information systems. This is achieved by applying a holistic approach and synthesising previous literature into a tentative framework. This framework is further improved by case studies and evaluation by experienced practitioners. Implications for practitioners are that it should help designers of handheld information systems to better apprehend the properties of handheld computing. It can be used as an analytical tool in the design process to ensure that the accentuated factors are appropriately recognized, or as a tool for analysing competing solutions in the procurement process. The accentuated factors framework also has implications for teaching. It can be used in system development education, mainly as an analytical tool in exercises on handheld computing.

The *HISD Toolkit* has theoretical implications as a contribution to the field of information system design research where agile methods are combined with the accentuated factors framework. Implications for practitioners are the collaborative toolkit applicable in the design of handheld information systems for the mobile workforce. The HISD Toolkit also has implications for teaching. It can be used in system development education, both in regular design exercises with agile methods and in more specialised design exercises on handheld computing. Being developed further than a description communicated with words, that is, the HISD toolkit does exist in a physical form, it is an example of an instantiation (Gregor 2006).

Regarding the four design propositions, *least common denominator*, *tune-in*, *defensive design*, and *flexible forms*.

Least common denominator is based on a grounded approach and has theoretical implications where it contributes to the knowledge base regarding the effects of the lack of standards on system development. Implications for practitioners are the detailed account of the settings of the developed system and the lessons learned by developers that lead to the suggested design proposition. *Tune-In* has theoretical implications as it contributes to our knowledge base on the off-task property among the mobile workforce by systematically investigating and presenting a design proposition to describe and manage off-task. Implications for practitioners are the design proposition that describe a real case solution that relies on automated responses to geographical data. *Defensive design* has theoretical implications as it contributes to our knowledge base regarding support issues. The importance of appropriate support is well recognised in mainstream information research; however it is less illuminated from a handheld computing perspective. Implications for practitioners are the design proposition and the real case based solution that informs practitioners on suggestions for providing solutions to reduce the need for support. *Flexible forms* have theoretical implications where they contribute to the debate on the movement to standardize and hard-wire operational processes, a movement that Hall & Johnson (2009) argue has gone overboard. With the design proposition, an alternative approach to the hard-wire movement is proposed, describing how an operational process can be flexibly designed. Implications for practitioners include the design proposition that offers a suggestion to designers and developers on how to manage the unpredictable nature of mobile work. Interesting in relation to *flexible forms* are the following: about one year after the interviews at ACME, I met one of the informants by coincidence and we started to talk about the system at ACME, the problems they had, and the suggestion that was put forth in the paper. The informant told me that the information system had been updated and functionality corresponding to flexible forms had been added. Whether this update was a result of my design proposition or a result of evolutionary design is not known. However, one can argue that the update of the system verified the value and applicability of the design proposition. Taken all four design propositions together as demonstrated in this study, they are all examples of abstract artefacts and the implemented solutions are instantiations (Gregor 2006).

There are additional contributions made in this dissertation, such as revised concepts within handheld computing for the mobile workforce, including the refutation of *anywhere* and *anytime* as trademarks of mobility and the introduction of the *digital ranger*. These conceptual contributions further improve future analysis and design of handheld information systems for the mobile workforce.

The *design science* approach applied in the cover and in six of the papers has theoretical implications as it contributes to the cumulative application of design science approaches and whereby builds a critical mass that will eventually earn design science the recognition as a science in its own right.

5.2 Reflections on research quality

Quality is fundamental to academic research. The suggestions of Moisander & Valtonen (2006) on how research should be reported act as guide for conducting quality research. They argue that a research report should exhibit the following features: *importance of the topic*, *theoretical implications*, *conceptual rigour*, *clarity of writing and argumentation*, and *methodological rigour*.

Regarding the *importance of the topic*, this is discussed in the introduction of the cover and in the papers and is furthermore implicitly approved by the information systems community, as paper 1–6 and 8 have been peer reviewed, accepted, and published. Paper 7 has not yet been published, however, have been peer reviewed and accepted. The *theoretical implications* are discussed in conjunction with the *implications for practice and teaching* in papers and in the previous section.

Conceptual rigour refers to the specification of concepts and theoretical perspectives, appropriate treatment of literature, and clarity of objectives.

In this dissertation, a design science approach is applied, which has an impact on the aim, method, and contribution. However, it this not a dissertation about design science research, rather it *applies* design science.

The cover is an unabridged piece of design science, and six out of eight papers have applied a design science approach. The research model, adopted from Carlsson et al. (2010), is a model developed for design science activities; hence the model corresponds to the approach. The implementation of the model and the applied research process correspond to the research cycle often discussed in qualitative research as the hermeneutic circle.

The design science approach has supported the view that goal-oriented, normative research is valuable in information system research. Furthermore, it has prompted suggestions on how to carry out design science research and formulate design contributions.

The unit of analysis, the IT-reliant work system (Alter 2006), corresponds to the core of IS research (Hevner et al. 2004) and the intertwined nature of organisations, technologies, and people.

It is difficult to prove or test *clarity of writing and argumentation*; however, some efforts are made to help the readers through the text. Opening paragraphs are used frequently, and each chapter has a concluding section where the contribution to the aim is clarified. In order to visualise how different parts interconnect to each other, tables and diagram were used. Furthermore, this cover is written with the objective that it can be read as a work in its own and does not necessitate reading the papers to be understood, relieving the reader from frequently shifting back and forth between cover and papers. Hence, a degree of redundancy is inevitable.

5.2.1 Reflections on empirical research

Regarding *methodological rigour,* as appropriate methods, appropriate and sufficient data, and rigorous and innovative analysis (Moisander and Valtonen 2006) are discussed in chapter three, and an enhanced reflection is presented below.

Being a cumulative dissertation with appended papers, a short discussion has already been presented in the papers regarding method and limitations. In this section, a more detailed account of methodological considerations and the research quality is given.

Generally stated criteria to ensure rigour in research are validity, reliability, and generalisability. However, there seems to be variation on the interpretation of those concepts, at least in the context of more qualitatively oriented work. It is argued that concepts of validity and reliability have their background in natural science research and are developed for quantitative methods, and that they are less appropriate and do not have the same bearing in behavioural and design-oriented research, see for example Lincoln and Guba (1985), Seale (1999), Silverman (2006). Lincoln and Guba proposed the concept of trustworthiness as the main indicator of quality in qualitative research. In other words, *"How can an inquirer persuade his or her audience (including self) that the findings of an inquiry are worth paying attention to, worth taking account of?"* (Lincoln and Guba 1985, p. 290). Trustworthiness is consolidated by a detailed account of the criteria's *credibility*, *transferability*, *dependability*, and *conformability*. However, these criteria do not oppose *validity*, *reliability*, and *generalisability;* instead they are, to a considerable degree, comparable with each other. *Credibility* has similarities with internal validity, *transferability* has similarities with external validity, *dependability* has similarities with reliability, and *conformability* has similarities with objectivity. Hence, these are quality measures that should be acceptable to both quantitative and qualitative proponents and the concept of trustworthiness are applied.

The empirical data come from five major activities: the three case studies (21st CMS, ACME, ASPEA), the semi-structured interviews on factors, and the experiments on toolkit evaluation. These activities are mapped to the criteria of trustworthiness.

Credibility is interpreted as social settings with multiple realities. If there exist multiple descriptions of one social reality, it is the credibility of the descriptions that assures trustworthiness (Lincoln and Guba 1985). In the three case studies, triangulation has been applied to ensure credibility in field findings. In 21st CMS, the grounded approach was complemented with document studies, confirmative reading (see section 3.6.2 on confirmative reading) and interviews with all employees. Following the interview in ACME with one respondent where a specific concept surfaced, four controlling interviews with other users were carried out to reduce the risk of deviant data. The presence of the concept was further studied in software, document studies, confirmative reading, and interviews with managers. In the ASPEA case, the information from the first presentation of the system was followed up with interviews with all employees and with document software studies and confirmative reading.

In interviews with practitioners, triangulation was not possible. Instead a version of member check was applied, i.e., new or modified factors were introduced in subsequent interviews, thereby controlling new factors via member checks.

Regarding *transferability,* qualitative studies most often cover a small set of informants and are characterized by depth and contextual dependencies rather than breadth and universal laws. This condition causes inherent problems when transferring findings from one social setting to another (Lincoln and Guba 1985). To manage this, researchers are advised to offer thick descriptions of the culture and thereby provide a means to judge the extent to which the findings are transferable into another context. Rich case descriptions in section 3.5 and extensive reporting on the applied method in section 3.6 aim towards this.

Dependability concerns the possibilities to examine the trustworthiness via an auditing stance (Lincoln and Guba 1985). This is achieved by presenting an exhaustive and transparent account of all activities in the research process, for example, the selection of informants, important decisions, modes for analysis, etc. To achieve reasonable dependability, all the steps in the research process are made visible via descriptions and the tables 17–20.

Concerning *conformability,* it is argued that there cannot be any flawless objectivity when qualitative methods are applied. Instead, the inquirer has to convince the audience that he or she has acted in good faith. It should be made evident that the researcher's bias has not impeded the theoretical stance or the analysis (Lincoln and Guba 1985). In order to increase conformability in the ACME case, the informants in the follow-up interviews were selected by the manager, without my interference. Regarding the interviews with experienced practitioners, I knew none of the informants in the evaluation in advance. They were all contacted via LinkedIn and had the opportunity to decline participation. Furthermore, they decided the location for the interviews. The informants in ASPEA and 21st CMS were all the employees at the two companies. The students doing the evaluation of the HISD-toolkit were voluntary participants in the workshops. These actions are means to reduce bias in the selection of informants.

5.2.2 Limitations

In this work a multitude of methods has been applied in five major empirical instances: the 21st CMS case, the ACME case, the ASPEA case, the interviews with experienced practitioners, and the experiments with students. As a corollary to applying a set of methods, the set of potential weaknesses increases with each different method applied.

The three cases were deliberately chosen to be different, to fulfil the aspiration to study the whole chain from server to end user. This lowers the transferability between case findings.

In the 21st CMS case the strategy was a grounded approach using participatory observations as a means to identify important lessons. One weakness is that my own interpretation of the important lessons guided me into further examination. To reduce that bias, developers were interviewed, confirmative readings of documents were carried out, and follow-up interviews with the operator technical staff were carried out.

In the ASPEA case, the developers' perspectives may have skewed the findings towards technical issues, downplaying end-user aspects such as control and privacy. Furthermore, regulations may affect the system and information handling, as the information displayed on screens may be patient data.

In the ACME case, service technicians were interviewed and documents and software were studied. The designer's objective for the system was not possible to investigate; therefore, the artefact and its use were studied. The focus was from the developer's perspective, on what lesson could be learned that others could apply.

As a consequence, important perspectives that could explain the design considerations were left out. That is, users and middle management were interviewed, leaving out the developers and senior management. There may be design considerations made to restrict the users' agency due to some unknown managerial decision.

Regarding the interviews with experienced practitioners, a weakness is the lack of triangulation or similar strategy to reach high rigour. A sort of member check was made, whereby the findings from the prior interviews where introduced in the following interviews. Furthermore, to improve rigour the first part of the interview did not concern the tentative framework; instead, the informant's own perception of handheld computing was discussed. In the latter part of the interview, the factors were introduced and mapped onto the properties, identified in the first part of the interview. This acted as a control for my interpretation of the interview and as a internal member check

Regarding the evaluation of the HISD Toolkit, the focus was on form rather than content and was done by students. There is a lack of evaluation of the content and input by experienced practitioners.

5.3 Retrospection and future research

This dissertation started with an argument that we are witnessing a technological change in the shape of wireless networks with higher capacity and increased geographical coverage, accompanied by more and more powerful handheld devices in the shape of smart phones. This technological change represents changes for the mobile workforce. The work on this dissertation started back in 2006, and during the years one can argue that we have witnessed a dramatic change within handheld computing. In 2006 few had heard of Google Android, and there were only unconfirmed rumours that Apple would launch a smartphone. However, that would soon change; in 2007 Apple launched the iPhone, and in 2008 the first Android smartphone was launched. These devices and operating systems got considerable news coverage and few have missed the smartphone and the App revolution. My interpretation is that the importance of handheld information systems for the mobile workforce will not diminish.

In conjunction with the smartphone and App revolution, it is important that the suggested framework, toolkit, and design propositions are independent of realising technologies, i.e., that the contributions are applicable to app development for example Blackberry, iPhone, and Android handsets.

Some reflections can be made about research on handheld information systems for the mobile workforce. The first paper (Andersson 2010) in the collection of papers was a literature review based on the tentative framework (see section 2.7). It showed that factors such as *supporting technologies*, *time dependencies*, *task dependencies*, and *field-use conditions* were less illuminated than factors explicit to handheld computing, such as the small form factor. That study also showed that research on the focal user group, the mobile workforce, accounted for only 14.7% of the examined publications.

The last paper in the collection of papers is another literature review (Andersson 2012b), based on the evaluated framework (see section 4.1) and examining what has been done from 2001 to 2010 in research on the design of handheld information systems. This displays a similar pattern; factors such as *field use conditions, support issues, supporting technologies*, and *time critical* were not mentioned in any of the examined publications, while factors explicitly for handheld computing were studied more, such as *location awareness*, *small form factor-interface*, *small form factor-hardware*, and *multimodal interfaces*. Regarding the focal user group, only 13.4% of the examined publications had the mobile workforce as the user in mind.

Comparing these two literature reviews, it can be seen that the distribution of research regarding accentuated factors is the same for both reviews and that factors that are of importance for the mobile workforce still need further systematic illumination. Regarding the mobile workforce as a user group, it has gained the same amount of research interest in both literature reviews. There remain areas worthy of further study regarding the factors presented above and the mobile workforce in general. These areas will be discussed in the following section.

5.3.1 Strengthen the accentuated factors framework

Although the accentuated factors framework is based on extant theories and empirical data it is, as far I know, the first attempt to develop a comprehensive framework capturing the unique properties of handheld computing for the mobile workforce. Two areas of enhancement of the framework are at hand, a *statistical confirmation of factors* and dependencies, and *thicker descriptions of factors*.

On *statistical confirmation of factors*, the empirical data upon which the accentuated factors framework is developed are chiefly qualitative data. In order to strengthen the framework, a thorough statistical test of the framework could be appropriate. The aim would be to validate the importance of the factors and to validate and increase the knowledge on dependencies. Important would be to study the underlying mechanisms of the dependencies between factors and further study of mediating factors would in order to enhance the explanatory power of the framework.

Regarding *thicker descriptions of factors,* thick descriptions of factors with more real case examples would be useful. At present, most of the factors identified in the literature are of a common-sense nature. Observations, case studies, or ethnographic studies could be useful tools to further investigate the nature or the factors and make them more thoroughly consummate.

5.3.2 Test the HISD Toolkit in development

The present version the HISD Toolkit is evaluated only on form, not content. With the aim of testing in what extent the HISD Toolkit has an impact on the design of a handheld information system; it must be tested in a real case.

However, to test a tool such as the HISD Toolkit is not a straightforward task. The possibilities to build and evaluate two parallel systems are not present; that would require a laboratory setting almost impossible to generate.

However, it would be possible to investigate differences between one real case and two parallel simulations using three groups of designers, isolated from each other and with the same information regarding the case at hand. All three groups should use the HISD Toolkit, and only one group's design will be developed.

After launch, the three different designs should be analysed and compared in order to identify differences. Afterwards, the developed and implemented systems in use would be investigated and retrospection on the design efforts could be made.

5.3.3 Fill in gaps – more design propositions

As identified in the literature review in paper 8 there are factors closely related to the work situation in need of further clarification. For example factors as *field use conditions*, *support issues*, *supporting technologies*, and *time critical*.

Regarding *field use conditions*, in mandatory use the user may suffer from not being able to choose in which conditions to use the system. If the information system is not developed to manage this conditions (hardware as well as software and other factors), the users may suffer diminished performance due to problems related to field use conditions. Although ethnographically inspired studies can inform designers in the nature of mobile work, design propositions and other suggestions how to handle field-use conditions are appreciated.

On *support issues*, if the support organisation is not designed to offer support in the field or the application is not designed to reduce the need for support, the usability of the system will be negatively affected. Here exists a need for empirical studies on what kind of support the digital ranger needs, and descriptions of methods to offer proper support or and design propositions to minimise the need for support are of value.

Concerning *supporting technologies*, if the handheld information system does not cover all information handling aspects, and the user must rely on additional resources, the geographical distance to those resources will affect the usability on the system. Research and design suggestions are warranted to suggest how to compensate for the lack of supporting technologies.

On *time critical*, poor design that does not take the just-in-time aspect into account will most likely negatively affect the usage of the system. Here there is a need for tested design principles on how to manage a range of aspects related to just-in-time. This is a difficult problem, where varying connectivity, security issues, and small form factor-hardware issues coincide.

5.4 Concluding remarks

At the beginning of this chapter, the aim of this dissertation was discussed as well as the contributions made. Here in the last section, a reflection on the central thesis propelling the study is presented. The central thesis in this dissertation is that a comprehensive approach towards management of the specific properties of handheld computing is necessary in order to design appropriate handheld information systems. Experienced practitioners in sixteen interviews confirmed this thesis when the framework was evaluated. Although more rigorous testing of the framework has yet to be carried out, the tentative framework has been proven valid in two simplified initial tests. That is, the tentative framework has been used as an analytical tool in the evaluation of an existing handheld information system in two cases (Andersson and Henningsson 2010a, Andersson and Henningsson 2010b).

Research within the information system domain is like shooting at a moving target; fuelled by technological advancements, information systems are constantly finding new and innovative uses and reaching new user groups, and handheld computing is a clear example of this.

For example, the informants argued that the speed of change is dramatically faster within handheld computing than within desktop computing. In February this year the Mozilla foundation in cooperation with Telefonica, one of the world largest mobile operator, launched the advent of Boot2Gecko (Mwc 2012). Boot2Gecko is an initiative from the mobile operator to compete with, and to deteriorate the dominance of Apple and Google regarding operating systems on handheld devices. Interesting is that Boot2Gecko architecture is distinctly different from iOS and Android, differences that may change some parts of the design and development of handheld information systems.

Attending to this persistent challenge to information system development, this study develops the accentuated factors framework and the HISD Toolkit, and to reduce the effects of the radically fast-changing nature of handheld computing, the accentuated factors framework and HISD Toolkit are of a generative nature rather than a normative nature.

Thus, the framework and the toolkit are in the form of a pattern language and a method, not the suggested final solution. As the nature of information systems is fast changing, evolving, and contextual, the generative nature of this dissertation corresponds to the nature of IT-reliant work systems.

However, this dissertation is not the end. The technology and innovations that triggered the need for the accentuated factors framework and the HISD Toolkit do not stop. In consequence, the accentuated factors framework and the HISD Toolkit cannot remain stable, but must coevolve along with innovation. Tomorrow might bring a technological innovation that solves the fundamental issue of handheld computing, or tomorrow might bring a technological innovation that increases the complexity of the design of handheld information systems.

And here emerge the Janus face of the framework and toolkit. The speed of change may outdate the framework and toolkit and making them obsolete, however, the speed of change makes it difficult for designers and developers to keep up to the changes. Hence, there will be a future need for both a framework and a toolkit as those proposed in this dissertation. The quest is to keep the framework and toolkit up to date.

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7 Appendix

7.1 Additional papers

Title	Mobile computing investigated: a review of what has been done in the domain of mobile computing research
Reference	Andersson, B. (2007) *Mobile computing investigated: a review of what has been done in the domain of mobile computing research*. Proceedings of the NOKOBIT 2007 Conference, Oslo.
Abstract	This review examines which research approaches have been used within mobile computing. Articles from 10 journals and three conferences from 1996 to 2000 have been examined and classified according to Järvinen's (2000) taxonomy, which is focused on research approaches. The purpose of this study is to increase our knowledge of the kind of research that has been conducted within the domain of mobile computing. The results indicate that during the last years, robust theories have been under development, although the majority of research concerns the building of IT-artefacts. A suggestion on how the topic could evolve is to enhance the development of theory in favour of describing artefacts.
Title	Issues in the Development of a Mobile-based Communication Platform for the Swedish Police Force and Appointed Security Guards
Reference	Andersson, B & Hedman, J. (2006) *Issues in the Development of a Mobile-based Communication Platform for the Swedish Police Force and Appointed Security Guards*. Proceedings of the Third International Conference on Information Systems for Crisis Response and Management, New Jersey.
Abstract	This paper presents the learning experiences from the development of a mobile-based communication platform, called OrdningsVaktsCentralen (OVC). OVC can be translated as Security Guard Central. OVC is designed to enable the Swedish Police Force (SPF) to comply with new legal requirements and enhance their collaboration with Appointed Security Guards (ASG). The focus of this paper is on the early phases of development and in particular on specific technical issues such as interoperability and standards used in the development of mobile-based systems. The learning experiences are as follows: firstly, when developing mobile-based systems we suggest and recommend that the analysis phase should be enhanced and it should address the interoperability between mobile phones on one hand and operators on the other. Secondly, global and national standards, such as the MMS7 for sending multimedia messages, are not always standardized. It seems that operators and mobile phone manufacturers make minor alterations and interpretations of the standards and as a result some of the benefits of the standards are lost. Thirdly, mobile-based communication platforms have a large potential for contributing to the field of emergency management information systems since they can be based on open and nationally accepted standards.
Title	Developing m-services; lesson learned from a developer's perspective

Reference	Andersson, B & Hedman, J. (2007) *Developing m-services; lesson learned from a developer's perspective.* Proceedings of the Global Mobility Roundtable, Los Angeles.
Abstract	In recent years the Swedish Police Force (SPF) has encountered greater demands on availability and 24/7 services when dealing with errands that are regarded as low priority compared to regular police work, e.g., collecting tips from the public. One attempt to meet these increasing demands was the development of a mobile communications platform that allowed the public to communicate easily with the SPF using their own mobile phones by sending SMS and MMS. The focus of this paper is on the early phases of development of this m-service, in particular, on the specific technical issues such as interoperability and standards used by the actors on the scene affecting the development of mobile information systems. The learning experiences are as follows. First, mobile communication platforms have a large potential for contributing to the field of emergency management information systems since they can be based on open and nationally accepted standards. Second, global and national standards for sending multimedia messages are not always truly standardized. Operators and mobile phone manufacturers make minor alterations and interpretations of the standard and as a result some of the benefits found in standards are lost. Third, when developing mobile information systems we suggest and recommend that the analysis phase should be enhanced compared to traditional system development, and it should address the interoperability between mobile phones and operators.
Title	About appropriation of mobile applications - the applicability of structural features and spirit
Reference	Andersson, B. (2008) *About appropriation of mobile applications - the applicability of structural features and spirit.* Proceedings of the 16th European Conference on Information Systems, Galway.
Abstract	This paper presents early findings of a study on how users appropriate a computerised mobile system designed to administer service orders. The theoretical lens used was Adaptive Structuration Theory (AST) and focused on structural features, spirit, and appropriation of structure. In order to accomplish the purpose, two aspects were considered—the system's structure and the user's appropriation—because the structure of a system affects the appropriation of the system. The study was conducted at a large international company's Swedish subsidiary operating in heavy industry, machines, and transportation. The methods used were a blend of several instruments, such as analysing documents, observations, and interviews. These qualitative empirical data were analysed from the perspective of AST. The initial results demonstrate that some of the tested constructs within AST are not applicable to computerised mobile information and therefore some adjustments must be made in AST to fit the mobile computing domain. In order to test these results further, at least two possible strategies lie ahead: either a closer study of the underlying assumptions of structural features and spirit or a broader test of more of the propositions in the AST framework.
Title	Use of mobile IS: new requirements for the IS development process
Reference	Andersson, B. & Henningsson, S. (2010) Use of mobile IS: new

	requirements for the IS development process. In: Isomäki, H. & Pekkola, S. (eds.) *Reframing Humans in Information Systems Development*. London, Springer.
Abstract	Not available, book chapter
Title	Developing mobile information systems: managing additional aspects
Reference	Andersson, B. & Henningsson, S. (2010) *Developing mobile information systems: managing additional aspects.* Proceedings of the European Conference on Information Systems (ECIS), Pretoria.
Abstract	Despite the numerous reports in academic journals and the business press of systems that fail to deliver anticipated benefits, mobile information systems (IS) are still gaining ground. The nature of mobile IS introduces additional aspects that require attention during the development process, compared to more traditional information systems built for stationary computers. The underlying assumption in this paper is that successful management of these aspects is crucial in order to harness the possibilities of mobility. This paper presents the AUDE (Application, User, Device, Environment) framework—an analytical framework that addresses the additional aspect of mobile IS. The framework integrates previous research on mobile IS and is tested retrospectively on a case involving mobile service technicians. Of the 19 attributes covered by the AUDE framework, two were not applicable in the investigated case. Of the remaining 17 attributes, only six were actively handled (three of them only partly), eight were not taken into account, and for three we were not able to retrieve data. With the ignorance of specific attributes for mobile IS development it was possible to explain why the developed IS did not meet expectations and was considered a failure by its users.

7.2 Interviews and demonstrations

Sources of information in the form of interviews and conversations in different forms

Informant	**Activity**	**Date/ Place**	**Medium**	**Duration (approx.)**
Aspea				
Per Sevrell, Richard Niclasson, Peter Håkansson	Demonstration and interview	April 2009, Malmö	Live, notes	3 hours
Per Sevrell, Richard Niclasson	Interview	May 2009, Lund	Live, notes	2.5 hours
Per Sevrell, Richard Niclasson	Interview	August 2009, Lund	Live, notes	3 hours
Richard Niclasson	Interview		Telephone, notes	0.5 hour
Manger KLT	Interview		Telephone, notes	1 hour

Hans Carlson, Dispatcher KLT	Interview		Telephone, notes	1 hour
Peter Håkansson Håkan Johansson, Developers ASPEA	Interview Demonstration		Live	4 hours
21st CMS				
Prototype developer: Mats Revesjö, Anders Rosén	Workshop participation	Twice a week February 2005–October 2005 (20 recorder WS)	Live, notes	Min 3 hours per session
Developer team: Tomas Hansson Mattias Nilsson, Jonas Fröier, Mats Revesjö Anders Rosén Mikael Rosvall Erik Rydgren (JW) Jyrki Vanio	Workshop participation	Weekly November 2005–May 2007, Lund (51 recorded WS)	Live, notes	Min 2 hours per occasion
Erik Engfors, Tele2, Stockholm	Conversations, technical errands, support, SLA, agreements	Weekly,	Live, telephone, email, mail	15 minutes to 3 hours
Helene Claesson, TeliaSonera, Stockholm		Monthly	Telephone, email, mail	15 to 30 minutes
Victoria Refsten, TeliaSonera, Stockholm		Monthly	Live, telephone, email, mail	15 minutes to 3 hours
Roger Ekström, TeliaSonera, Stockholm		Weekly	Telephone, email, mail	15 minutes to 3 hours
Örjan Sanfahl, TRE, Stockholm		Monthly	Telephone, email, mail	15 to 30 minutes
Maria Holmsten, TRE, Stockholm		Monthly	Telephone, email, mail	15 to 30 minutes
Ove Beijer, Telenor, Karlskrona		Monthly	Telephone, email, mail	15 to 30 minutes
Olle Svensson, Telenor, Karlskrona		Weekly	Telephone, email, mail	15 to 30 minutes
Erik Engfors, Tele2, Stockholm	Concluding interview	April 2007	Live	60 minutes
Roger Ekström, TeliaSonera, Stockholm			Telephone	45 minutes
Örjan Sanfahl, TRE, Stockholm			Telephone	45 minutes
Olle Svensson, Telenor, Karlskrona			Telephone	60 minutes
ACME				
ST Alpha	Interview	October 2007	Live	1 hour

ST Alpha	Demonstration	October 2007	Live	4 hours
ST Alpha	Interview	December 2007	Live	2 hours
ST Beta	Interview	December 2007	Telephone	0.5 hours
ST Gamma	Interview	December 2007	Telephone	0.5 hours
ST Delta	Interview	December 2007	Telephone	0.5 hours
Clerk Adam	Interview	December 2007	Telephone	0.5 hours
Clerk Bertil	Interview	December 2007	Telephone	0.5 hours
Dispatcher Cesar	Interview	December 2007	Telephone	0.5 hours
Experienced practitioners				
David Pettersson, 8 years' experience, Cybercom	Interview	December 2010, Lund	Live	1.5 hours
Mathias Svensson, 6 years' experience, Mashmobile	Interview	December 2010, Lund	Live	2 hours
Ants Patrik Maran, 11 years' experience, Qubulus	Interview	January 2011, Malmö	Live	1.5 hours
Christer Östergaard, 7 years' experience, Stratal	Interview	January 2011, Lund	Live	1.5 hours
Fredrik Gemzell, 11 years' experience, Cybercom	Interview	January 2011, Stockholm	Live	2 hours
Gunnar Forsgren, 14 years' experience, Mobimation	Interview	January 2011, Stockholm	Live	2.5 hours
Fredreric Henricsson, 4 years' experience Yahm	Interview	January 2011, Lund	Live	1.5 hours
Eric Wetterberg, 5 years' experience, Qliktech	Interview	January 2011, Lund	Live	1.5 hours
Johannes Petersson, 6 years' experience, Databolaget	Interview	January 2011, Lund	Live	2 hours
Himzo Music, 5 years' experience, Softhouse	Interview	March 2011, Malmö	Live	1.5 hours
Christer Mårtensson, 14 years' experience,	Interview	March 2011, Lund	Live	1 hour

Cybercom				
Andreas Sjöström, 13 years' experience, Sogeti	Interview	April 2011, Lund	Live	1 hour
Terese Andersson, 11 years' experience, Cybercom	Interview	April 2011, Malmö	Live	1 hour
Mats Karlsson, 12 years' experience, WIP	Interview	April 2011, Karlskrona	Live	1.5 hours
Conny Svensson, 5 years' experience, Logica	Interview	April 2011, Göteborg	Live	2 hours
Matias Sauber, 3 years' experience, Sigma	Interview	April 2011, Malmö	Live	1.5 hours

7.3 Document and artefact studies

Sources of information in the form of documents, e-mail, software, hardware, program code

Artefact	Activity	Output	Medium
21st CMS			
Ericsson SMPP Specifications and API	Content comparison to find evidence for standardisation or platform proliferation	Matrix describing differences and similarities	Paper documents
Ericsson MM7 Specifications and API			
IPX SMPP Specifications and API			
IPX SMPP Specifications and API			
Tele2 SMPP Specifications and API			
Tele2 MM7 Specifications and API			
TeliaSonera SMPP Specifications and API			
TeliaSonera MM7 Specifications and API			
TRE SMPP Specifications and API			
TRE MM7 Specifications and API			

Telenor SMPP Specifications and API			
Telenor MM7 Specifications and API			
myMSP Specifications	Study of implemented solutions		Paper documents
myMSP API, Web service descriptions	Study of implemented solutions		Paper documents
myMSP program code	Study of implemented solutions		Paper documents, digital program code
myMSP database architecture	Study of implemented solutions		Paper documents, ER-diagrams, digital program code
Aspea			
WinHast	Study of implemented solutions		Paper documents, website, program
ACME			
Handheld information system	Study of implemented work processes		Paper documents, program
Manuals, teaching materials	Study of implemented work processes		Paper documents, presentations
E-mail	Study of implemented work processes		Paper documents

7.4ACME questionnaire

Introduction to the interview

Background information on informant	Position? Age? Years of experience of the system?
Opening up the interview	Detailed job description Workflow * Has your work changed since implementation of the system?
On the system	Thick description of the HIS
Theme Structure	Does the system direct you, or do you direct the system use? Is it a rigid or flexible system? Does the system have a lot of advanced features or not? Does the system have all necessary features or not?
Theme Spirit	Is it a democratic system or not? Are all users equal or not? Can you communicate and negotiate with other users?
Theme Appropriation	How do you use the system? Do you follow the intended use and workflow? Do you use other aids to do the information work? Do you combine different tools? Does any tool or device change the meaning?
Overall impression of the system	Describe in a few sentences the pros and cons of the system. What is your overall grading of the system? *Do you save or waste time with the new system? *As a percentage, to what extent do you manage repairs? *As a percentage, to what extent do you manage information and reports?
Other	Do you have any other opinions or are there any other matters that we not yet discussed during this interview?

7.5 ASPEA questionnaire

Introduction to the interview	
Presentation of my research	
Background information on informants	Experience? Role/roles? Type of applications/systems/services?
Reflections regarding the development of WinHast	Semi-structured discussion
Specific	QoS Maintenance Support Geographical distance
The design principles	Seven principles?
Functionality	Specific features?
Available data	Screen shots Source code Manuals
Other	Do you have any other opinions or are there any other matters that we not yet discussed during this interview?

7.6 Tentative framework questionnaire, phase 1

Introduction to the interview	
Presentation of my research	
Background information on informant	Company? Experience? Role/roles? Type of applications/systems/services? Platforms? End user groups?
The informant's view on differences between development of stationary and mobile applications/systems/ser	Especially important factors, ranging from technology, requirement engineering, and end user.

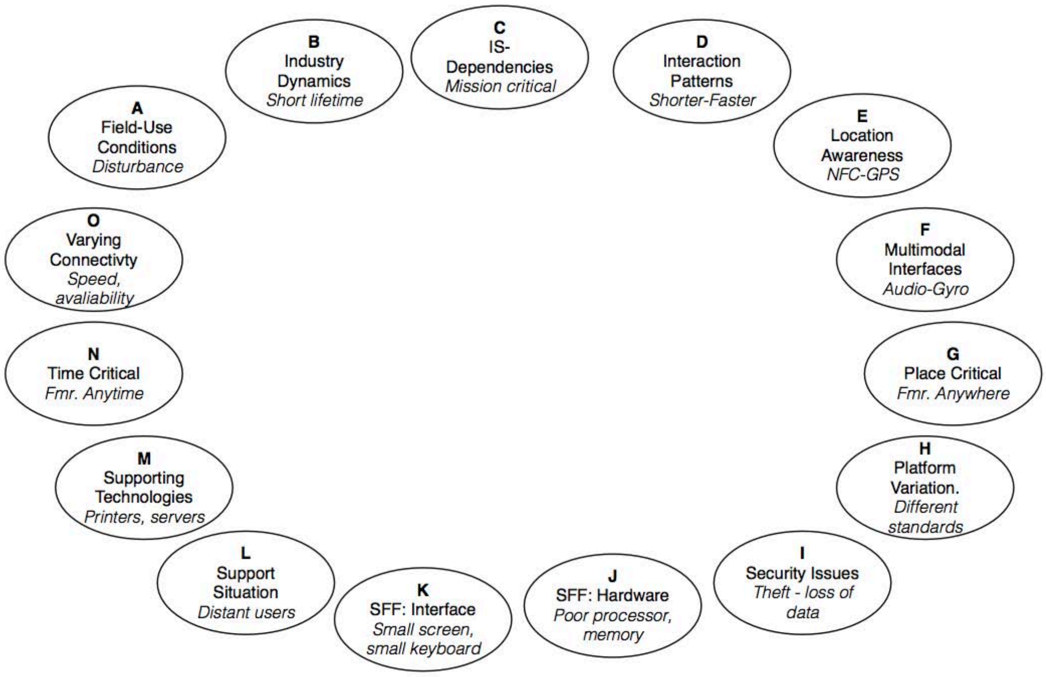
vices.	

Discuss the factors and the theoretical framework (comparison)

Evaluation:	The questions are not always asked directly. If possible, they are implicit in the discussion.
Completeness	Are all the presented factors of importance in the design and development of handheld applications? Are there any factors missing from the presented set? Are there any factors that should be removed from the set?
Distinctiveness	Are there any overlapping factors that would benefit from merging Into an existing factor? Into a modified factor? Into a new factor? Are there factors that would benefit from separation into more factors? Are there factors that should be formulated in some other way? If yes, how? Change header? Change description?
Simplicity	Are the names of the factors (headers) natural and easily understood? Could the names of the factors be different/better/more descriptive? Are the descriptions of the factors sufficient, clear, and easily understood? Do the descriptions convey the main characteristics for the actual factors? If not, which should be altered and how should they be formulated?
Other	What is your opinion on the importance of a framework like this? If you should group the factors someway, how would you group them? Can the factors have different importance in different contexts (different applications)? Are there factors that are dependent on other factors? Who could be a potential reader of a framework as such? How should the framework be presented/illustrated/displayed to a potential reader? Do you have any other opinions, or are there any other matters that we have not yet discussed during this interview?

7.7 Tentative framework questionnaire, phase 2

Introduction	Presentation of me and my research
Background data on informant	Company Type of experience Years of experience Role/roles in development Types of applications/services/systems Which platforms? Types of end users
Short introduction of the concept of factors	Are new Changed meaning / new interpretation Changed importance / more or less important
Present all the factors	Explain that these originate from literature and research.
Try to establish a conversation involving the factors	
General	Ask the informant to group factors into important and less important groups.
Specific	Ask the informant to estimate the importance of each factor in a specific case. Are there any missing factors? Should any factors be excluded? Overlap-disjoint properties?
Use the diagram (see figure below)	Ask if the informant can identify dependencies between factors. Check marks.



Dependencies:	Might the dependencies have different importance in different cases? Are there any indifferent dependencies?
Factors	Might the factors have different importance in different cases? Are there any indifferent factors?
Wrap up	Are there any other opinions or aspects not covered so far in this interview?

7.8 Toolkit first evaluation

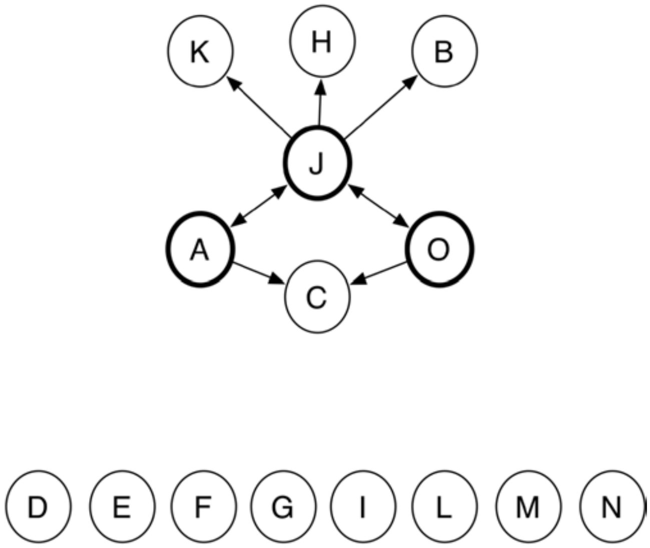
Task
Build two network diagrams (one for each case displayed below) illustrating different factors' importance in two reality-based cases.
Case A
Design a mobile patient journal and medication control system. Use the blue cards! At Kalmar County Council, homecare is provided to elderly and chronically ill patients. Kalmar County Council intends to invest in a mobile information system to increase the quality of the service. Ambulatory nurses equipped with written medication schedules travel to patients to make sure that the patients receive the medication as prescribed and to follow up on other treatments and conditions. The work is geographically scattered and the nurses may drive up to 250 kilometres per day. For most patients, the timing of medication is crucial, and they have to be medicated at certain hours of the day. The patients who need medication assistance are grouped into three categories: Class 1 – needs timely medication, life-supporting medication; Class 2 – important, but not critical; Class 3 – can skip one or two days of medication without serious consequences. To ensure that Class 1 and Class 2 patients receive their medication on time, the nurses call the healthcare facility after each Class 1 and Class 2 medication. The head nurse monitors all ambulatory nurses and if one call is missing measures are made to ensure that the patient gets medication somehow. Regarding Class 3, the nurses send an email after a workday. Twice a month, the nurses meet at the healthcare facility for one day to update their schedules and other information.
Case B
Design a mobile service order system for service technicians making field service. Use the red cards! ACME, a firm operating in heavy industry, machines, and transportation, intends to purchase a tailor-made system for their service technicians (STs) to shorten information management time. A shorter time from service to sent invoice is crucial. ACME has mobile STs who operate from the firm's service trucks (each contains a small workshop and spare parts). On an ordinary day, the ST leaves his home, travels directly to the client's facility, and starts working on the servicing of the client's machinery. After completing a day's work, the ST drives directly home. Ordering spare parts is done by phone, and the postal service or a transportation firm delivers the spare parts. Each ST manages all services in their region, an area approximately 400 * 400 kilometres. The workflow is as follows. The customer calls the service order office requiring a service or repair. A service order is created and sent to the ST by postal mail. The ST plans the work schedule, travels to the customer facility, and carries out the service or repair. After a service/repair is completed, the ST fills in a service order sheet and sends it to the main office. At the main office, a clerk enters the data into the ACME ERP system and an invoice is created and sent to the customer.

Method Group 1

Preferably use a whiteboard or similar

Important: Start with Case A, finalise it, and then start with Case B. Do NOT construct the two diagrams simultaneously.

Arrange the factors according to the figure below. Factors A, J, and O are, in general, considered the most important factors.



Discuss factors in order of importance; the perspective must be the actual case. Some factors will most likely be more important than other factors. Evaluate each factor's relation to other factors' importance and whether the factor really is necessary in the project at hand. Make notes on decisions made.

Some factors will most likely influence more factors than other factors. Discuss relations between them and illustrate them with interconnecting lines. Identify positive-negative links and strong-weak links. Insert arrows to explain the direction of influence. Make notes on decisions made.

You are free to rearrange the initial diagram.

Remove unimportant factors from the network.

Repeat the procedure and evaluate the rest of the factors and relations (B,E,G,I,L,M,N), one at a time.

Output

Two different network diagrams with nodes (factors) and edges (relations). These diagrams can be used to discuss and evaluate a proposed design.

Method group 2

Preferably use a whiteboard or similar

Important: Start with Case A, finalise it, and then start with Case B. Do NOT construct the two diagrams simultaneously.

Arrange the factors randomly on the whiteboard. Discuss factors in order of importance; the perspective must be the actual case. Some factors will most likely be more important than other factors. Make notes on decisions made.

You are free to rearrange the factors any way you please.

Describe relations between them with lines (edges). Some factors will most likely influence more factors than other factors. Make notes on decisions made.

Output

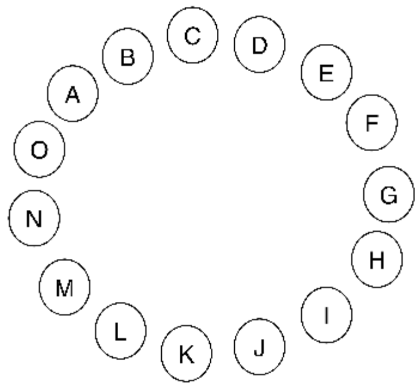
Two different network diagrams with nodes (factors) and edges (relations). These diagrams can be used to discuss and evaluate a proposed design.

Method group 3

Preferably use a whiteboard or similar.

Important: Start with Case A, finalise it, and then start with Case B. Do NOT construct the two diagrams simultaneously.

Arrange all factors in a circle (alphabetically), see figure below.



Discuss factors in order of importance; the perspective must be the actual case. Some factors will most likely be more important than other factors.

Describe relations between them with lines. Some factors will most likely influence more factors than other factors. Draw lines (links) between factors, illustrating relations between factors. Identify positive-negative links and strong-weak links.

You are allowed to do minor adjustments in layout to enhance readability of lines; however, try to retain something that looks like a circle. Try to elicit where to start your design, that is, which factors should be prioritised.

Output

Two different network diagrams with nodes (factors) and edges (relations). These diagrams can be used to discuss and evaluate a proposed design.

7.9 HISD Toolkit second evaluation

Introduction

HISD is a design aid with the aim of supporting designers and developers in identifying important factors in a specific design case. The form is inspired by the Scrum technologies Scrum Wall and Scrum Cards.

It is based on the assumption that the most influential factors should be considered and managed before less important factors are considered and managed.

The method is built on the accentuated factors framework and the dependencies between these factors.

Disclaimer: The method does not provide any solutions, nor does it provide any predefined patterns. It is a communication tool usable in communication between designers, developers, customers, and users.

A key aspect is the ability to reduce the risk of neglecting important factors and reducing the risk of reengineering due to misinterpretation regarding importance of factors.

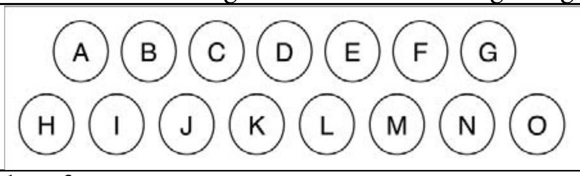
Method group 4

Quick Start

Read this “Quick Start” section completely first.

Preferably use a whiteboard or similar.

At the bottom of the whiteboard, arrange the factors according to figure 1.



Discuss factors in order of importance.
The perspective must be the actual case.
Some factors will most likely be more important than other factors.
Evaluate each factor’s relation to other factors.
The perspective must be the actual case.
Identify strong and weak dependencies.
Illustrate the strength of dependencies between factors.
Insert arrows to display direction of dependencies.
This will build a network diagram.
Identify positive and negative dependencies.
Positive dependencies can be a feature.
Negative dependencies are likely problems to manage.
Only the factors important to the case should be represented.
Rearrange the factors when necessary.

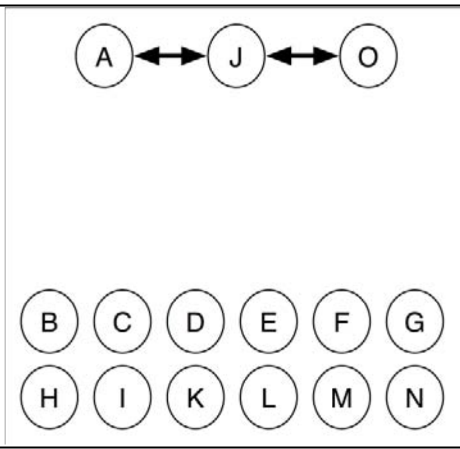
Method group 5

Quick Start

Read this “Quick Start” section completely first.

Preferably use a whiteboard or similar.

At the bottom of the whiteboard, arrange the factors according to figure 1.



Discuss factors in order of importance.
The perspective must be the actual case.
Some factors will most likely be more important than other factors.
Evaluate each factor’s relation to other factors.
The perspective must be the actual case.
Identify strong and weak dependencies.
Illustrate the strength of dependencies between factors.
Insert arrows to display direction of dependencies.
This will build a network diagram.
Identify positive and negative dependencies.
Positive dependencies can be a feature.
Negative dependencies are likely problems to manage.
Only the factors important to the case should be represented.
Rearrange the factors when necessary.

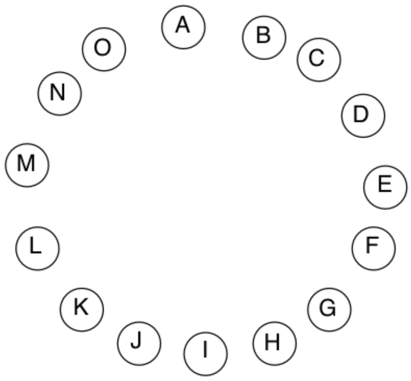
When finished, the most influential factors should be identified, and these are the most important factors to consider. Relying on this information, design considerations can now be made.

Method group 6

Quick Start
Read this “Quick Start” section completely first.

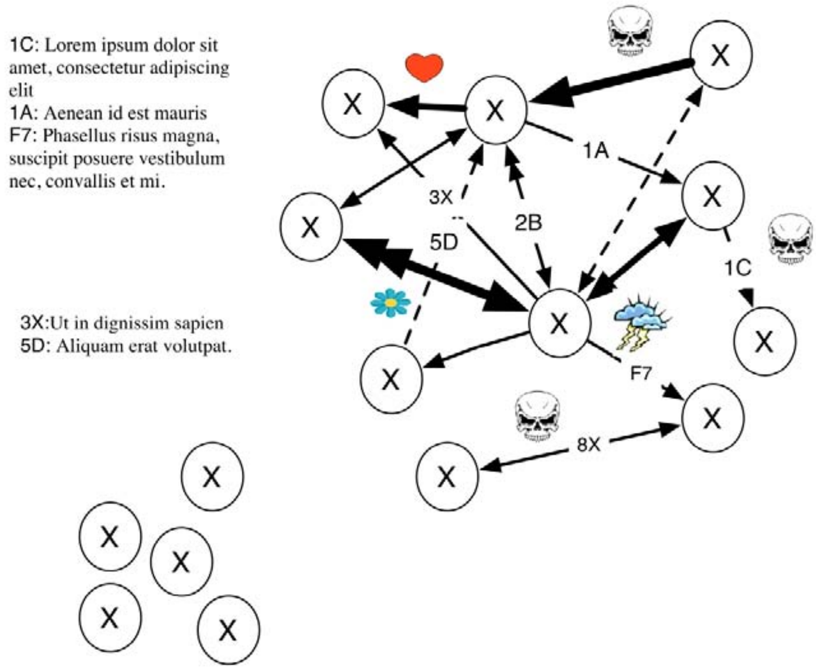
Preferably use a whiteboard or similar.

At the bottom of the whiteboard, arrange the factors according to figure 1.



Discuss factors in order of importance.
The perspective must be the actual case.
Some factors will most likely be more important than other factors.
Evaluate each factor's relation to other factors.
The perspective must be the actual case.
Identify strong and weak dependencies.
Illustrate the strength of dependencies between factors.
Insert arrows to display direction of dependencies.
This will build a network diagram.
Identify positive and negative dependencies.
Positive dependencies can be a feature.
Negative dependencies are likely problems to manage.
Only the factors important to the case should be represented.
Rearrange the factors when necessary.

When finished, the most influential factors should be identified, and these are the most important factors to consider. Relying on this information, design considerations can now be made.



For all groups:

Short descriptions of factors

On the concept of accentuated factors, the term accentuated illustrates either that a factor already exists but has gained greater importance or exists but has changed its properties when the factors are managed from a handheld computing perspective, or that it is a new factor entering the system development domain when a handheld computing system is to be built. This leaves the overlapping factors between mobile and stationary computing out of scope.

The term factor illustrates a feature or circumstance contributing to or affecting design and developmental efforts (adapted from the New Oxford Dictionary, i.e., a circumstance, fact, or influence that contributes to a result or outcome). The small form factor and connectivity are examples of factors in mobile computing. Factors can be described by their properties, such as small screen or varying transmission rates. The accentuated factors framework is composed of the following 15 factors (Andersson & Henningsson, 2011):

Field-Use Condition

For the mobile workforce, most work is obviously done in the field resulting in a use situation often labelled as field-use conditions. This factor regards the physical surroundings as being quiet or noisy environments, with sunlight, darkness, heat, or low temperature all influencing the field use in their own way. A lack of a predefined workplace is also a part of this factor; mobile workers need to adapt to different and diversified workplaces.

Industry Dynamics

This illustrates the fast-changing environment with competing vendors, manufacturers, and content providers, and it is argued that this factor is more fierce and withstanding compared to within stationary computing. A high-velocity environment exists in stationary computing, but the importance of this factor is greater in handheld computing.

The lifecycle of an application is shortened for a handheld device due to the shorter expected lifetime of the device itself, with more frequent changes in operating system versions (with a low degree of backward compatibility) and faster changes in carriers, platforms, etc.

Information System Dependencies
With regards to the mobile workforce's high reliance on their information systems, if an implemented application is the only application the user may access, and this application is crucial for the user to conduct the work, the reliance on this application is high. If the application malfunctions, or the implemented workflow does not match the actual/real workflow, these problems will have extensive negative impact on the perceived usefulness and productivity.

Interaction Patterns
This factor illustrates that it is anticipated that the mobile user benefits from short interaction sequences, short time periods of use, and aversion to long boot sequences, and that active behaviour is patterned to manage this. The main reason is that the mobile workforce is often occupied with tasks other than working with their computer.

Location Awareness
Handheld devices are mobile and therefore able to appear in different places, and they can by different means use the information of their physical location. This location awareness can be achieved by GPS, triangulation, accessing nodes, or other techniques. However, location and context may overlap to a varying extent and where appropriate context is included in location awareness.

Multimodal Interfaces
Refers to new I/O possibilities, such as motion control or LDR sensors. This factor is closely related to the small form factor, however, a separation of concern is argued. Multimodal interfaces are an extension rather than the reduction that the small form factor is often considered as.

Place Critical
Anywhere is almost a trademark of handheld computing, which represents freedom of place, however in a work situation the interpretation of freedom of place can be questioned. The authors argue that for a mobile workforce and mandatory use the user is most likely not allowed to choose the place; on the contrary, the place may be specific. A "just in place" requirement is more applicable.

Platform Variation
The mobile industry is characterised by a large and heterogeneous set of actors and stakeholders. This creates a complex ecosystem with competing technologies and standards that in turn affect designers trying to design systems which are functional on different platforms. In respect to this set of actors, and in the case of handheld applications, the platform variation is large, meaning large variations in operating systems among the handhelds and a large variation in hardware configurations.

Security Issues
In wireless communication, security issues are present due to the risk of interception. There may be different types of threat such as masking, listening, browsing, and

distortion. Another security issue is the small form factor and its omnipresence. The handheld device's small size means that it will be carried around to a greater extent than, for example, a laptop computer. This frequent exposure increases the risk of it being stolen or lost (greater exposure in foreign environments) compared to, for example, a desktop computer. These two security issues are both illustrated by the Security Issues factor.

Small Form Factor – Hardware
Due to the miniaturisation of hardware, hardware capacity is limited compared to desktop computers. For example, the limited power supply is highly relevant for mobile devices, since in practice they are required to be battery powered and independent of fixed power networks. The effects of this are reduced processing capability, limitations in storage, etc. Even if the capacity of handheld's hardware increases, there will most likely be a difference.

Small Form Factor – Interface
This factor concerns the small form factor with a small screen and limited keyboard. The keyboard may not be present, or there may be a keyboard offered which has a limited set of keys compared to an ordinary keyboard.

Support Issues
This factor illustrates issues related to providing support to geographically distributed users. The fact that a considerable part of the mobile workforce is working by themselves in the field renders a lack of colleagues with which to interact in an informal fashion. The coffee room interaction may be missing, and furthermore the sheer physical distance can cause problems in offering support.

Supporting Technologies
Compared to the office worker, the mobile workforce's accessibility to supporting technologies is often limited. Important documents may not be easily accessed and displayed through a handheld device. File management, servers, fax machines, written manuals, written ledgers, or other support systems may not be available to the same extent as in an office environment.

Time Critical
One trademark of handheld computing is anytime, usually describing the fact that the user can access certain information, services, or applications whenever they want, providing freedom in time. In contrast with the concept of freedom in time, when members of the mobile workforce actually do need information, it is often relatively time-critical information, such as the repair status on a machine or a purchasing status just before a client meeting, making "just in time" a more accurate term to illustrate the mobile workforce and mandatory use relationship to freedom in time. For clarity of the possible restrictions on anytime, the label "Time Critical" is put forward in replacement of anytime.

Varying Connectivity
This factor illustrates the unpredictability of Quality of Service, both in transmission rate and connectivity. With wireless networks, disconnection is a factor which needs to be managed. Temporary disturbances such as sun flares, road tunnels, interference, and skip zones affect transmission.

7.10 Case description second evaluation

THE COMPU CASE

Introduction

Compu is a fictive case constructed by the author. The workshop supervisor has extensive knowledge of the industry due to previous studies of the industry and service technicians' work; therefore, the supervisor will act as the customers' representative and may be asked questions for clarification during the workshop.

Settings

Compu, a firm operating in heavy industry, machines, and transportation, intends to purchase a tailor-made system for their service technicians (STs).

The ST maintains customers' pallet trucks and fork lifts (see figure 1), carrying out regular maintenance and repairs. The service is always performed at the customer's facility, be it inside the customer's own workshop, at the plant, or out in the field.

Figure 1. Different models of pallet trucks and forklifts

Expectations on future system

Compu expects faster and more accurate invoice handling. Today, the time from a customer call requesting a repair to invoice sent by mail is an average of four weeks. From Compu's perspective, these weeks cost a considerable amount of money in lost interest. The reason for the slow invoice handling is twofold: first, the ST is writing the invoice specifications on paper and sending them by postal mail, and second, there exists a considerable amount of ambiguity in the invoice specification, requiring administrative staff to do extra work such as calling the ST for clarification. The ambiguity may be illegible handwriting, non-existent spare part numbers, invalid customer addresses or customer IDs, etc.

Compu are interested in purchasing a computerised handheld information system in order to manage the alleged problems. Compu has studied other systems for service technicians and has some requirements on realising technologies (see appendix A).

Figure 2. Competing information system.

Present situation
The mobile work shop
Compu has mobile STs who operate from the firm's service trucks, each containing a small workshop and the most common (or pre-ordered) spare parts (see figure 3).

Figure 3. ST workshop van

Receiving assignments
The customer calls Compu's service desk and requests a service, and the dispatcher at the service desk arranges the assignments. STs receive assignments from Compu dispatchers mainly via postal mail or sometimes via phone if urgent.

Workflow of an ST
The ST plans the work most often a week in advance and is expected to optimise travels. On an ordinary day, the ST leaves home, travels directly to the client's facility, and starts working on servicing the client's equipment. After completing a day's work, the ST drives directly home.

If an assignment is urgent, the dispatcher at Compu calls and informs the ST.

After completed service, the ST fills in the “Invoice Specification form”, see appendix B, and sends it via postal mail to the administration at Compu.

Ordering spare parts is done by phone or via postal mail, and a transportation firm delivers the spare parts to the ST’s home address. Each ST manages all service in their region, an area approximately 400 * 400 kilometres.

COMPU CASE Appendix

A: Realising technologies

Backbone ERP
API to SAP ERP is available
Operator contract
Flat rate contract with unlimited Internet and voice call
Customer choice of handset
Xperia Active, a water- and dust-proof mobile phone

Size: 92.0 × 55.0 × 16.5 mm / 3.6 × 2.2 × 0.6 inches
Weight 110.8 g / 3.9 oz
Screen: 320 x 480 Pixels / 16,777,216 colour TFT / 3 inches /
Platform: Android
Memory: Internal phone storage: 1 GB (up to 320 MB free) / RAM: 512 MB Memory card slot: microSDTM, up to 32 GB

Compu AG

INVOICE SPECIFICATIONS

Service Staff

Service technician ID	
ST Name	
Service Date	

Customer Details

Customer ID	
Customer Name	
Service Location	

Machine Information

Machine ID	
Machine Name	

Mileage Data

Date	To - From	Mileage	Hours

Service Performed

Date	Action	Hours

Spare Parts Used

Item ID	Item	Quantity

7.11 Final version of the HISD Cards

A: Field-use conditions
These illustrate that there may be variation in environmental conditions where a mobile device can be used. Examples are possible environmental factors such as noise, rain, excessive heat, excessive cold, and strong/weak ambient light, which may affect how the user interacts with the handheld device. For the mobile workforce, most work is obviously done in the field, resulting in a use situation often labelled as field use conditions. This factor regards the physical surroundings as being quiet or noisy environments, with sunlight, darkness, heat, or low temperature all influencing the field-use in their own way. A lack of a predefined workplace is also a part of this factor; mobile workers need to adapt to different and diversified workplaces.
B: Industry dynamics
This illustrates that hardware, software, and ancillary systems are changing rapidly and that it can be difficult to design applications that are functional for longer time periods. Examples are the expected short turnaround time for both operating systems and handheld devices. This also illustrates the fast-changing environment with competing vendors, manufacturers, and content providers, and it is argued that this factor is more fierce and withstanding compared to within stationary computing. The lifecycle of an application is shortened for a handheld device due to the shorter expected lifetime of the device itself, with more frequent changes in operating system versions (with a low degree of backward compatibility) and faster changes in carriers, platforms, etc.
C: Information system dependency
This illustrates that if the mobile information system is the only information system, the user may be highly dependent on this information system. One example is the comparison with "mandatory fields on a website". A solution to consider is the Flexible Forms design proposition. With regards to the mobile workforce's high reliance on their information systems, if an implemented application is the only application the user may access, and this application is crucial for the user to conduct the work, the reliance on this application is high. If the application malfunctions, or the implemented workflow does not match the actual/real workflow, these problems will have extensive negative impact on the perceived usefulness and productivity.
D: Interaction patterns
These illustrate that the mobile workforce is often busy with tasks other than information processing. Shorter or other interaction patterns are often requested.

An example is the "Fire and Forget" patterns. A solution to consider is the Tune-In design proposition.

This factor illustrates that it is anticipated that the mobile user benefits from short interaction sequences, short time periods of use, and aversion to long boot sequences, and that active behaviour is patterned to manage this. The main reason is that the mobile workforce is often occupied with tasks other than working with their computer. Consider if Tune-In or similar design propositions can be valuable.

E: Location awareness

This illustrates the handheld device's ability to learn the current geographic position.

Examples are triangulation, RFID, NFC, or GPS.

Handheld devices are mobile and therefore able to appear in different places, and they can, by different means, use the information of their physical location. This location awareness can be achieved by various techniques.

F: Multimodal interfaces

These illustrate that other modes of interaction can occur than traditionally occur on the desktop.

Examples are motion sensors, camera, gyro, microphone, NFC, RFID, and positioning, which open up new interaction scenarios.

Referring to new I/O possibilities using various techniques, this factor is closely related to the small form factor; however, a separation of concern is argued. Multimodal interfaces are an extension rather than the reduction that the small form factor is often considered as.

G: Place critical

This illustrates the need to use the information system in a particular place. The condition "mandatory use" means that the users are not free to use the information system anywhere. (Anywhere is not fully applicable in this mandatory environment.)

Examples are the service technician who may need blueprints for a specific machine in connection with service on the shop floor.

Anywhere is almost a trademark of handheld computing, which represents freedom of place; however, in a work situation the interpretation of freedom of place can be questioned. It is argued that for a mobile workforce and mandatory use, the user is most likely not allowed to choose the place, on the contrary, the place may be specific. A "just in place" requirement is more applicable.

H: Platform variation

This illustrates that the heterogeneity and large set of stakeholders such as manufacturers and service providers increase the variation in standards and available platforms.

Examples are different interpretations of the JAVA standard between different phone models. A solution to consider is the Least Common Denominator design proposition.

The mobile industry is characterised by a large and heterogeneous set of actors and stakeholders. This creates a complex ecosystem with competing technologies and standards that in turn affect designers trying to design systems which are functional on different platforms. In respect to this set of actors, and in the case of handheld applications, the platform variation is large, meaning large variations in operating systems among the handhelds and a large variation in hardware configurations.

I: Security issues

These are twofold: security threats for the wireless transmission and the risk of losing the handheld device.

Examples are the possibility of interference and distortion concerning wireless transmission and the greater risk of being lost than a desktop computer.

In wireless communication, security issues are present due to the risk of interception. These may be different types of threat such as masking, listening, browsing, and distortion. Another security issue is the small form factor and its omnipresence. This frequent exposure increases the risk of it being stolen or lost (greater exposure in foreign environments) than, for example, a desktop computer. These two security issues are both illustrated by the Security Issues factor.

J: Small form factor hardware

This illustrates that hardware performance is affected by miniaturisation as a result of its small size.

Examples are limitations in memory capacity, battery capacity, computing capacity etc.

Due to the miniaturisation of hardware, hardware capacity is limited compared to desktop computers. For example, the limited power supply is highly relevant for mobile devices, since in practice they need to be battery powered and independent of fixed power networks. The effects of this are reduced processing capability, limitations in storage, etc. Even if the capacity of handheld hardware increases, there will most likely be a difference.

K: Small form factor interface

This illustrates that possibilities for interaction are different as a result of miniaturisation.

An example is the limited screen size.

This factor concerns the small form factor with a small screen and limited keyboard. The keyboard may not be present, or there may be a keyboard which has a limited set of keys compared to an ordinary keyboard.

L: Support situation

This illustrates that the geographical distribution of users can increase the complexity in offering support.

Examples are digital rangers with a low degree of interaction with other peers or support staff. A solution to consider is the Defensive Design design proposition.

This factor illustrates issues related to providing support to geographically distributed users. The fact that a considerable part of the mobile workforce is working by themselves in the field means a lack of colleagues with whom to interact in an informal fashion. The coffee room interaction may be missing, and furthermore, the sheer physical distance can cause problems in offering support.

M: Supporting technologies
These illustrate the greater variation in the availability of other support resources. Examples of this are the users who work without a proper home base, for whom the availability of support resources such as libraries, manuals, fax machines, and printers are often limited. Compared to the office worker, the mobile workforce's accessibility to supporting technologies is often limited. Important documents may not be easily accessed and displayed through a handheld device. File management, servers, fax machines, written manuals, written ledgers, or other support systems may not be available to the same extent as in an office environment.

N: Time critical
This illustrates the need to access the information system at a particular time. An example of this is a mobile vendor who might have to get a payment at a specific time. It originates from the concept of "anytime" but is a clarification based on the conditions that apply to an employee's mandatory use of an information system. There are contexts where the user cannot choose when a task is to be performed but is forced by external circumstances. Anytime describes primarily the freedom to perform tasks at any time, whereas time-critical means "right now".

O: Varying connectivity
This is twofold: both transmission speed and accessibility can vary. Examples are the possibility of different transmission rates depending on the current network and the ability to connect to the network. In some cases, the transmission rate can be virtually non-existent or connections are disrupted due to poor coverage or other reasons.

PART TWO

Appended papers

Paper 1: Andersson, B (2010). *Mobile computing from a developer's perspective: a 10-year review, 1999-2008.* Proceedings of the 9th International Conference on Perspectives in Business Informatics Research. Rostock.

Paper 2: Andersson, B. and Henningsson, S. (2011). *Accentuated Factors of Handheld Computing.* Proceedings of the 20th International Conference on Information Systems Development. Edinburgh.

Paper 3: Andersson, B (2012) *Enhancing the Accentuated Factor Framework: Dependencies Between Factors*. Accepted at European Conference on Information Systems. Barcelona

Paper 4: Andersson, B. and Hedman, J. (2007). Developing m-Services: Lessons Learned from the Developers' Perspective. *Communications of the Association for Information Systems*. 20.

Paper 5: Andersson, B. and Carlsson, S. A. (2009). *Designing for Digital Nomads: Managing the High Reliance on Single Application*. Proceedings of the Global Mobility Roundtable. Cairo.

Paper 6: Andersson, B. and Keller, C. (2010). *Harness Mobility: Managing the Off-Task Property*. Proceedings of the International Conference on Design Science in Information Systems and Technology. St. Gallen.

Paper 7: Andersson, B. (2011). *Harnessing handheld computing – Managing IS support to the digital ranger with defensive design*. Proceedings of the Sixth International Conference on Design Science Research in Information Systems and Technology. Milwaukee.

Paper 8: Andersson B. (2012). *Handheld Computing from a Design Perspective: A 10-year Review - 2001-2010.* Proceedings of the 45th Hawaii International Conference on System Sciences. Maui.

Due to copyright restrictions the papers are excluded in this online version of the dissertation.