Pers Ubiquit Comput (2013) 17:1261–1279
DOI 10.1007/s00779-012-0634-y

ORIGINAL ARTICLE

A toolbox for managing organisational issues in the early stage of the development of a ubiquitous computing application

Daniel Boos · Gudela Grote · Hannes Guenter

Received: 10 January 2012 / Accepted: 14 December 2012 / Published online: 10 January 2013

Abstract In this paper, we present a toolbox for the prospective management of organisational issues in ubiquitous computing. Ubiquitous computing applications are developed to enable new services and new ways of working, to increase management control and to improve safety. However, they may also interfere with established work practices and may have unforeseen consequences for organisations. Despite their importance, such organisational issues are rarely addressed in ubiquitous computing innovation projects. Drawing on socio-technical design approaches and existing research on organisational issues in ubiquitous computing, we have developed a toolbox containing three tools for managing organisational issues of ubiquitous computing applications in the early stage of development. The toolbox supports the realisation of hoped-for benefits of ubiquitous computing in organisations and the management of unwanted organisational issues. The "work process tool" supports the description of envisioned work processes, including flexibility and variability requirements, changing responsibilities and different points of view. The "work system tool" analyses the alignment between a ubiquitous computing application and work systems task completeness, independency and the fit between regulation opportunities and requirements. The "human controllability tool" assesses how the control capabilities of workers are enabled or constrained by the new ubiquitous computing application. We show the applicability of the toolbox using a case study of an early stage ubiquitous computing technology innovation project, where the toolbox contributed to the set-up of the field trial and the development of application guidelines.

Keywords Organisational issues · Ubiquitous computing · Early stage · Benefits and risks · Socio-technical design

1 Introduction

The use of ubiquitous computing technologies has important socio-technical implications for organisations [cf. 53, 56, 69]. For example, ubiquitous computing technologies enable new services, new processes, new ways of working and improve management control and supply chain management [cf. 12]. However, ubiquitous computing technologies also pose challenges for organisations, because they may interfere with established work practices and lead to a lack of user control [43, 45, 46, 71].

Misalignments between ubiquitous computing applications, tasks and users provoke failures in organisations. How to deliver the expected results with a new ubiquitous computing application is a persistent challenge for system developers [26, 55, 60, 75]. Misalignments often arise in later stages of the design process or after implementation [39, 61]. A range of studies attributes the high failure rate to problems in predicting and managing potential misalignments of technology, tasks and users in early stages of technology innovation [23, 37, 39, 78]. Therefore, it is imperative to anticipate and address misalignments early in

D. Boos (✉) · G. Grote
Department of Management, Technology, and Economics, Organization Work and Technology Group, ETH Zurich, Zurich, Switzerland
e-mail: dboos@alumni.ethz.ch

G. Grote
e-mail: ggrote@ethz.ch

H. Guenter
Department Organisation and Strategy, Maastricht University School of Business and Economics, Maastricht, The Netherlands
e-mail: h.guenter@maastrichtuniversity.nl

the technology innovation process [35, 78]. Often, however, such potential misalignments are not addressed in the early stages of technology innovation, which may have various reasons, such as: the generally low importance attributed to misalignments in the early stage; the development of generic systems without accounting for the specifics of the work environment and the focus on technological feasibility [9].

Except for several explicit calls for developing socio-technical design approaches for ubiquitous computing applications [56, 60, 69], the topic of how to predict misalignments has received relatively little scholarly attention. While socio-technical design methods exist for advanced manufacturing systems, office automation and software engineering [2, 15, 25, 28, 35, 59], less is known about their use for ubiquitous computing applications. Also, socio-technical design methods mostly focus on the later stages of technology innovation, that is, the implementation phase. They address how difficulties due to misalignments might be reduced during the implementation phase of a new technology in an organisation. In this stage, work systems and end-user are already clear, the technology is mostly developed and knowledge exists about potential difficulties of use in organisations. Existing design methods, however, do not speak to the difficulties of addressing misalignments in the early stage of technology innovation projects. In the early innovation stage, only first ideas, prototypes and mock-ups exist, and it is not yet clear whether these prototypes will be deployed in an organisation. It follows that existing socio-technical design approaches need to be adjusted for the use in the early stage of the development of a ubiquitous computing application [56, 69].

The outlined gap is addressed in this paper by presenting a toolbox consisting of three tools to manage organisational issues evolving in envisioned socio-technical systems that use ubiquitous computing technologies. The term "organisational issue" is used to describe issues related to organisation and humans that need to be addressed during technology development to achieve a desirable output [cf. 15, 22, 23, 24]. The toolbox supports the realisation of hoped-for benefits of ubiquitous computing in organisations and enables managing unwanted organisational issues already during the early stage of technology innovation.

The paper is structured as follows: First, it provides a brief introduction in organisational issues in ubiquitous computing by summarising the vision of ubiquitous computing, followed by an overview on existing research on organisational issues and approaches to address them. Second, it describes requirements for a toolbox, our rationale for the selection of the tools and the development of the toolbox in a technology innovation project. Third, it describes the tools in detail, including an illustrative example. Finally, in the discussion, the applicability of the tool is assessed and implications for future development of ubiquitous computing technologies and further development of tools for the management of organisational issues are derived.

2 Ubiquitous computing and organisational issues

Most work in the domain of ubiquitous computing refers to the vision of Weiser [76] and the following quote: "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are undistinguishable from it" [76, p. 91]. Ubiquitous computing can be said to aim for the integration of information and computing technologies and everyday objects. Radio frequency identification tags (RFID) in combination with information systems can be regarded as a first step towards the realisation of the vision of ubiquitous computing. For example, scholars and practitioners have invested much effort into integrating RFID tags into goods to allow real-time monitoring and tracking throughout the supply chain [31, 58]. Many other applications are envisioned, for example, in health and safety, transportation, environmental monitoring, education or even tourism [57].

Despite many positive predictions about the future growth of deployed ubiquitous computing applications, most ubiquitous computing applications still only exist in research laboratories, where they are conceptualised and researched through scenario studies, system demonstrations, prototypes and trials with technology mock-ups. Only very few real-world deployments exist, for example, in libraries, in biometric passports and subway tickets [42, 46, 65, 67]. In many cases, the end-user and the usage are not yet clear and questions on technological feasibility are the main preoccupation of developers [9].

2.1 Research on organisational issues of ubiquitous computing applications

Research in future business benefits and in tools for assessing such benefits exists [3], but less is known about potential misalignments between ubiquitous computing applications, tasks and users and how to manage them. In fact, most research in non-technical issues of ubiquitous computing focuses on the societal impact [cf. 8]. For example, technology assessment studies look at the impact of ubiquitous computing on privacy, identity, trust and the digital divide [47, 77] or at its impact on health and the environment [40]. The number of studies focusing on organisational issues is comparatively small. Drawing on Doherty and King [23], we have grouped existing research into four types of organisational issues, namely,

Table 1 Overview of organisational issues

Category	Issue	Studies of ubiquitous computing applications (examples)
Organisational contribution	Cost and benefit assessment	Baars et al. [3]
	Business driver and benefits identification	Bose et al. [12] Fleisch and Mattern [32] Fleisch and Tellkamp [33]
	Alignment with corporate strategy	Günter et al. [38]
	Re-engineering business process	Baars et al. [3] Ramchand et al. [65]
Organisational alignment	Impact on organisational structure	Ramchand et al. [65] Kortuem et al. [48]
	Impact on power distribution	Spiekermann and Pallas [70] Kinder et al. [44]
	Cultural implications	Kinder [43]
Human-centred issues	Privacy issues	Lahlou et al. [49] Spiekermann and Langheinrich [72]
	Impact on individual control capabilities	Kjeldskov and Skov [45] Barkhuus and Dey [4] Spiekermann [71]
	Impact on individual work tasks and needed skills	Ramchand et al. [65] Günter et al. [38]
	Human–computer interaction	Belotti and Edwards [6] Benford et al. [7]
Transitional issues	Aligning established work practices with new ones	Konomi and Roussos [46]

organisational contribution, organisational alignment, human-centred issues and transitional issues. Table 1 provides an overview of organisational issues discussed in the literature.

The first type of organisational issues called organisational contribution describes ubiquitous computing technologies' contributions to the performance of organisations. There is a growing body of research assessing costs and benefits of ubiquitous computing technologies, studying value creation, business benefits and business drivers that make it economically attractive to use ubiquitous computing technologies [3, 32, 33]. Many of these studies focus on the domain of logistics and identify operational benefits such as a reduction in manual errors due to the elimination of the so-called media breaks or improved stock management due to more accurate information [cf. 12, 65]. These benefits are explained with the technological capacities of ubiquitous computing and its effect on automation, information gathering and the re-design of business processes [3]. Strategic considerations regarding corporate branding issues, for example, the repositioning of a company as a technology leader, can also foster the investment in ubiquitous computing applications [38]. A critique of current research in organisational contribution issues is that it predominantly addresses benefits and puts less emphasis on potential drawbacks and challenges [41].

Organisational alignment issues focus on the match between social aspects of an organisation, such as organisational structure, power and culture and the proposed technology innovation. While often not explicitly addressed as a change in organisational structure, many studies describing benefits of re-engineering business processes imply such a change of the organisational structure [65]. Some research suggests that ubiquitous computing technologies may help control the behaviour of employees, indicative of an increased centralisation of decision-making [70]. Some research, however, contradicts this finding. Kinder et al. [44], for example, suggested that an increase in data—available to both managers and employees—might actually work in favour of employees because the availability of data would legitimise their demands towards managers [44]. Other research argues that the technological design solution chosen has an effect on centralisation effects. While a centralised monitoring system works in favour of a centralisation of responsibilities, decentralised and distributed small computing devices allow for a decentralisation of the responsibilities [48]. Similar to findings from the information systems literature [cf. 5, 61, 66], no conclusive evidence concerning centralisation or decentralisation effects can be found. Furthermore, culture may mitigate the effects of ubiquitous computing applications and influence the perception of a ubiquitous computing application. The perception of the purpose of a ubiquitous computing application depends on the organisational culture and on previous experiences with other information and communication technologies. For example, employees may perceive a ubiquitous computing application as a surveillance tool by a hostile management or may think of the application as supporting their work activities [43].

Human-centred issues are those issues that have a discernible impact on the working practices and working conditions of those employees who interact directly with a system. Privacy issues are some of the most often studied human-centred issues, because ubiquitous computing applications allow collecting large amounts of data; this creates fears in users concerning a loss of privacy and an increased and unwanted transparency of individuals' activities [49]. Human–computer interaction issues are also investigated in the domain of ubiquitous computing technologies. Individuals may feel less in control while using ubiquitous computing applications [4, 45]. Perceived control over a ubiquitous computing application is an important reason for the acceptance of ubiquitous computing solutions [70]. Employees abandon or circumvent ubiquitous computing applications if the application does not facilitate exactly those tasks the worker needs to perform. Short delays in the reaction time of a ubiquitous computing application are regarded as especially troublesome [46]. Automation may also lead to a deskilling of employees but possibly also to an up-skilling of other employees as they take over back-office tasks and more service-oriented tasks [65].

Transitional issues concern organisational issues, which need to be addressed to ensure that the transition from an old to a new technology does not lead to disruptions. Research on transitional issues is quite sparse, due to the fact that not many ubiquitous computing applications are actually deployed and the large-scale deployment of newly developed ubiquitous computing applications is only expected to take place several years in future [1, 21, 57].

2.2 Addressing organisational issues of ubiquitous computing applications

Various approaches to address some of the identified organisational issues of ubiquitous computing applications already exist. First, ethnographic approaches are used to inform design in the domain of ubiquitous computing [cf. 17, 18]. Ethnographic approaches are used as a way to collect field experience and as a means for requirement gathering. Their emphasis is to understand the context of use of a ubiquitous computing application and to adapt the application to this context. Ethnographic approaches mainly support addressing organisational alignment and human-centred issues. Second, in situ evaluation of a prototype is another proposed method for addressing organisational issues [20]. In situ evaluations adopt previously developed concepts of research from psychology and human factors. In difference to an in vitro evaluation of a ubiquitous computing application (i.e. an experimental lab trial with students), an in situ evaluation (i.e. at the site of use with potential end-users) can better account for everyday life aspects of human actors and the unpredictability of the so-called real-world environments [20]. In situ evaluations mainly focus on human-centred issues. Third, new guidelines are proposed by human–computer interaction design approaches for designing interactions with sensors [7]. Sensors embedded in everyday objects demand new interaction models beyond the conventional graphical user interface. In particular, intelligibility of ubiquitous computing systems actions is put forward as a major requirement [6]. Fourth, economical cost and benefit analyses focus on the organisational contribution of ubiquitous computing and on the interests of managers who need to decide whether a certain technology should be used in an organisation [3]. Finally, participatory design approaches are also being used in the domain of ubiquitous computing and in the early stage of technology design [cf. 13]. By including different stakeholders, participatory design approaches allow addressing a variety of organisational issues, such as organisational contribution issues, organisational alignment issues and human-centred issues. Having outlined already existing approaches for addressing organisational issues of ubiquitous computing applications, we now introduce our toolbox and its background in socio-technical design.

3 Development of a toolbox for managing organisational issues

For the development of the toolbox, we followed the steps outlined by Woods and Dekker [78] to anticipate and predict effects of a novel technology on organisations. They recommend to first gather empirical knowledge and to build models and explanations of effects of a novel technology on organisations. As a second step, they recommend to use these models and explanations to anticipate consequences of a novel technology and based on these findings to stimulate design or develop precaution strategies. Our first step, accordingly, is about the development of tools and we describe this step in the following section. Our second step is about the use of the tools for a ubiquitous computing application, which we describe in the toolbox section below, where we explain each tool individually.

3.1 Requirements of an applicable toolbox

Calls for socio-technical design-based approaches for ubiquitous computing [54–56, 69] point to the issue that ubiquitous computing applications are part of socio-technical systems. First, it is therefore important that a toolbox does not solely look at separate parts, such as the technical system in isolation, but rather looks at the whole socio-technical system, including organisation and humans [37]. All aspects of a socio-technical system are interconnected and they need to be designed jointly [16]. Second, the toolbox should build on values and a mindset in line with socio-technical principles. These principles include that humans are regarded as an asset, technologies should support humans in achieving their goals and tasks should be motivating [16, 34]. Next, high levels of individual and collective self-regulation should be fostered [35]. The tools should also have specific criteria providing guidance on how to guarantee humane work design. Third, for anticipating organisational issues early enough in the innovation process, the toolbox needs to be adapted for an early stage of the technology innovation, which is the stage between market and technology assessment and first prototyping or application trials [19]. Therefore, the toolbox should be useable, when first real usage scenarios are defined, prototyping activities are outlined or application trials are performed. Fourth, to foster the use of the toolbox, it needs to be usable and useful for team members of a technology innovation project, even if team members are mostly non-experts in the domain of organisational issues. Fifth, the toolbox should stimulate design and innovation. This includes, on the one hand, support for the realisation of benefits of ubiquitous computing applications and on the other hand, the development of precaution strategies. The toolbox needs to provide guidance and support for design decisions in regard to organisational issues. In addition to fostering innovation, the toolbox should not only be of value for an evaluation of the prototype or usage scenarios developed in the project, but also for the larger exploration activity of the early stage technology innovation project. In fact, prototypes developed in such projects also function as a "kind of experimental probe and tool for discovery" [78, p. 279] beyond their use inside the project for a field trial. Prototypes and usage scenarios are often only one output of early stage technology innovation projects. Of similar importance are the project's dissemination activities, such as written deliverables, application guidelines, reports or presentations about the ubiquitous computing application towards stakeholders. For example, EU funded early technology innovation projects are not only held accountable for developing and testing a prototype of an envisioned ubiquitous computing application outlined in their work plan, but also for the dissemination of research results to relevant stakeholders. Therefore, outputs of the toolbox should also support dissemination activities.

3.2 Tool selection and theoretical background

Following Woods and Dekker [78] and based on the specified requirements, we selected three tools for our toolbox (see Table 2 for an overview). The most addressed issues of organisational contribution are cost and benefit analysis and the re-design of business processes. Issues of re-designing business processes are already an important topic during the early stage of technology innovation. We provide the "work process tool" for the re-design of business processes. The tool supports team members in the design of work processes based on findings from research in organisational routines and the narrative network approach [62]. The tool helps to take into account the relation between the actual performance of a work process in practice and the abstract pattern in a description of a work process, such as descriptions of standard operation procedures. Often descriptions of a work process are mistaken by designers for a carried out work process in organisational reality. Variations are considered to be something to eliminate or at least not worth supporting [64]. One single way of performing a work process is regarded as the correct and most efficient one. In contrast, studies show that variations are better regarded as a common phenomenon and an important source of change [30],

Table 2 Overview of the tools' operational criteria

	Criteria
Work process tool	
Changing responsibilities and functional allocation	Redistribution of responsibilities between different actors, work systems and/or technological systems with the introduction of a ubiquitous computing application
Flexibility requirements	Increasing or decreasing capacities of involved actors to flexibly adjust the work process to the situation at hand
Points of view	Conflicting views on sequence of action, including responsibilities and flexibility requirements
Further information	Grote [37]; Pentland and Feldman [62, 64]
Work system tool	
Task completeness	Functional integration of parts of a production or service process in a work system with a new ubiquitous computing application
Independence of work system	Dependency on other work systems and the ubiquitous computing application for task fulfilment
Fit between regulation requirements and regulation opportunities	Changing fit between regulation requirements of a work system and the regulation opportunities it has due to the introduction of a new ubiquitous computing application
Further information	Grote et al. [35]
Human controllability tool	
Human control	Required control capabilities of a human actor to fulfil responsibilities
Alignment with existing work activities	Fit between existing work activities and newly introduced ones
Further information	Boos et al. [10]; Grote et al. [35]; Grote [37]; Spiekermann [71]; Bellotti and Edwards [4]

as support for flexibility [36] or as a way to improve the overall performance [63]. Several studies have also shown that lacking flexibility for actors and a rigid prescription of work processes without variations can lead to circumvention, non-adoption or rejection, because workers might experience difficulties in performing their work activities and in coping with local contingencies [14, 37, 64, 75]. By building on the narrative network approach [64], the "work process tool" allows managing organisational issues due to the re-design of business processes with a ubiquitous computing application. This includes issues such as requested flexibility, changing responsibilities and different point of views about flexibility needs and responsibilities. Coping with problems at the source becomes possible if flexibility is available. The capability to properly assign responsibilities can be used to increase self-regulation. This is in line with socio-technical design principles. The narrative network approach is suitable for early stage technologies, because it allows using descriptions of work processes from different sources and provides a way to reflect on organisational issues. A benefit of using the narrative network approach compared to other methods of representing work flows in organisations, for example flow charts, is that it allows to represent a broader range of variations and possibilities showing sequences of events and more than one version of a process [62]. As many tools for the assessment of financial costs and benefits already exist [3], we decided not to provide an additional tool for it.

Attempts at re-designing business processes through technology also have an impact on organisational structure and therefore on organisational alignment issues. Ubiquitous computing applications change tasks of work systems where they are deployed. Therefore, it is important to analyse their alignment with an existing work system based on the "work system tool". Analysing the context of use and existing work practices allows us to better align the developed technology and the work system. The work system includes all workers, technical systems, materials, etc. required to fulfil the primary task of the whole work system. Realistic descriptions of tasks and activities of a work system are revealed, which allow for critically situating the technology within a more realistic context of use [74]. Faulty or too vague assumptions about the work system in the early stage of technology development need to be identified and addressed [52]. This helps to develop sound usage scenarios and to prevent misalignments of technology and work systems. The tool is based on shortened guidelines used for the work system analysis in KOMPASS [35]. KOMPASS consists of a range of criteria, which in case of fulfilment lead to a well-designed work system according to socio-technical design. KOMPASS offers theoretically sound and empirically tested criteria to assess the impact of automation on those factors. At the level of the work system, KOMPASS aims at self-regulation in small control loops [35]. The boundaries of a work system can be defined by its primary task for which the system was created. We selected three criteria, which mainly allow evaluating whether the self-regulation capability of a work system is positively or negatively affected by the ubiquitous computing application.

Human-centred issues are in a way already addressed in early stage technology innovation projects and there are several approaches on how to address them. In particular, the approaches are used with the testing of a prototype in a field trial. Concerning human-centred issues, we adjusted and combined some preexisting approaches to develop our tool [6, 35, 51]. We named the tool "human controllability tool". The focus is on human control over technical systems and alignment with work activities of employees, including the perception of the usefulness of the envisioned ubiquitous computing application for work. Human control is an important element of socio-technical design approaches. It fosters motivating work tasks and supports individual self-regulation [37, 50, 68]. Several approaches already provide guidance on how to address human control in ubiquitous computing applications [4, 6, 71]. As there is already a range of tools for privacy and as privacy seems to be of more importance in ubiquitous computing applications for private users, we do not address privacy issues in detail with our tool [cf. 29, 50, 72].

Transitional issues, especially the timing of an implementation, are less relevant in early stage technology innovation projects, because the deployment only can be expected in several years. We decided not to provide a particular tool for transitional issues.

4 Research setting: development and application of the toolbox

4.1 A research project on managing organisational issues

We developed the toolbox as part of a research project (from 2006 to 2009) on organisational issues in ubiquitous computing. The project aimed to identify organisational issues associated with ubiquitous computing technologies and to examine possibilities for predicting and managing organisational issues in early stages of technology innovation projects. In the context of the project, we had access to one research lab involving academic and corporate researchers and two publicly funded research projects involving partners from academia, business research and industry. In addition, we studied one deployed RFID system in two public libraries.

The tools were applied and iteratively refined during and after our participation in one of the publicly funded research projects, namely SToP (Stop tampering of Products) [73]. First versions were part of the trial evaluation and some of the results were used in the final deliverables of the project. The guidelines, questionnaires and descriptions of the approach were given to team members of the project for feedback. The selection of the tools for the trial evaluation was discussed with team members of the project. The trials of the project were used to test the toolbox. After the trial, the tools were adjusted based on findings about their applicability.

4.2 Illustrative case study—SToP project

For the illustration of our tools, we provide results from our participation in the SToP project [73]. The SToP project is one of the publicly funded research projects we studied. The project ran for 30 months, involved partners from academia, business software research, technology providers and potential industrial end-users. The project aimed at developing new solutions for assessing the genuineness of pharmaceutical products, luxury goods and aviation parts with the help of a ubiquitous computing application. The technical solution (a so-called product verification infrastructure) consisted of a management information system, enriched goods with unique identification computing technologies (e.g. RFID or 2D barcodes), reading devices and a network connecting all these devices. Future users would be provided with a reading device and by scanning the RFID tag or 2D barcode, would be able to immediately verify whether a product was genuine or not and distant investigations would become possible. The potential use of the technology was investigated at different points in the supply chain in the three industries. In the case of luxury goods, these points were a customer service point that clients could bring a watch to for repair, and a distribution centre, where handbags were packed and shipped to stores (see Fig. 1). In the case of the pharmaceutical industry, the point of dispense was in the focus—where pharmaceuticals are sold to a customer—and the point of incoming goods—where pharmaceuticals are delivered to a pharmacy (see Fig. 2). For aviation, the focus was on parts replacement, where a part of an airplane is replaced with a spare part. At all these points, new verification checks were meant to be introduced to immediately notify local and eventually distant actors about whether a product was genuine or suspected to be a counterfeit or tampered product.

The technological capability to gather track and trace data in an unprecedented granularity about goods movement was of particular importance for identifying suspicious products. The unique identification of a product allowed to validate its identity and to produce an alert in case of suspicious issues, like a not registered product, a duplicate, an already sold product or an unexpected delivery path.

A first version of the toolbox was applied in the pharmaceutical goods trial and two luxury goods trials. The pharmaceutical trial was done in two different pharmacies

Fig. 1 Trial sequence in distribution centre—packing of luxury goods for delivery

Fig. 2 Trial sequence in pharmacy—delivery of pharmaceutical goods to a pharmacy

in autumn 2008. Each trial lasted a day. The luxury goods trials were done in a retail store and a distribution centre in summer 2008. The trial in the distribution centre was performed twice with a duration of 2 days. The trial in the retail centre was also performed twice with a duration of a day. Between the two trial rounds, several improvements were made to the ubiquitous computing application, for example, the reading device was improved. Supervisors and employees participated in all the trials and used the prototype. The "work system tool" was used before the trial. For the "work process tool", information was gathered before the trial from different stakeholders and during the trial from supervisors and employees. The "human controllability tool" was applied during and immediately after the trial performance.

5 The toolbox for managing organisational issues

In this section, we present the three tools for managing organisational issues of ubiquitous computing technologies. Table 2 provides an overview of the tools and their main criteria. For the presentation of our tools and for ease of understanding, we use a structure similar to Clegg et al. [15]. We first describe the tool. Second, we describe the scope, purpose and outcome of the tool. Third, we describe in detail how the tool is used, including prerequisites for using it. Finally, we indicate when and where the tool is best used. Following each tool's description, we demonstrate the applicability with one illustrative case.

5.1 The work process tool—describing variability and flexibility needs of work processes

5.1.1 Introduction and tool criteria

The "work process tool" helps to describe and to visualise a future work process by collecting and combining different descriptions of involved stakeholders about the current work process (without the ubiquitous computing application) and the envisioned work process (with the ubiquitous computing application). The tool addresses three different criteria contributing to successful establishment of a future work process with a novel ubiquitous computing application. The first criterion is about making visible how responsibilities are redistributed between different human actors, organisational actors and the ubiquitous computing application. The second criterion is about guaranteeing that the ubiquitous computing application supports necessary variations of a work process. The third criterion is about different points of view of different stakeholders on the work process of interest. Table 3 provides an overview of the tool.

5.1.2 Scope, purpose, benefits of use and outcome

The tool can be best used for analysing ubiquitous computing applications that are process oriented and in places where changes to existing business processes or work processes are expected. The tool allows investigating work processes of different lengths and numbers of involved actors, for example, a short sequence of work activities or a large and long business process involving several organisations. The purpose is to extend the team members' views on an envisioned work process involving their ubiquitous computing application.

The potential benefits are that this allows having a structured approach to identify relevant sequences of actions, required flexibility for variations of envisioned work processes, divergent points of view and relevant actors involved. Of great value is the taking into account of multiple points of view and not solely the view of some team members or simplified use case diagrams [64]. Divergent views about the sequence of actions, performed activities by actors, flexibility requirements for variations, attributed responsibilities and goals of actors might be a source of disturbance and lead to a conflict of interests in case they are not taken into account.

The outcomes are an improved envisioned work processes for the ubiquitous computing applications and a more detailed description of them. The "work process tool" also allows the identification of actors and work systems, which will use and interact with the ubiquitous computing application directly as part of their work activities. The list of actors can be used for the "human controllability tool". The list of work systems affected can be used for the "work system tool".

5.1.3 Description of how to use the "work process tool"

A prerequisite for using the "work process tool" is the selection of a work process, which is newly created or changed with the envisioned ubiquitous computing application. In an early stage of a technology innovation project, this might be quite difficult, because ideas on usage scenarios may often change or are not available in great detail. Also the start and ending point of the work process need to be provisionally defined. As a guideline, the investigation should be started from the first to the last instance that the ubiquitous computing application is introduced. A team member can start with the investigation once it is clear which work process to study.

First, the team member needs to define which points of view to collect. The different points of view of particular interest are those of: designers, describing the future systems; industry partners, describing the intended use inside the organisation; employees, potentially using the system

Table 3 "Work process tool": summary and illustration

	Description	Example: pharmacy case
Scope and purpose	Design a work process where a ubiquitous computing application is used	Establish a new verification technology in an existing supply chain of pharmaceutical products, namely inside a pharmacy
Prerequisites	First process-oriented usage scenarios exist	Usage scenario in a pharmacy
	Access to potential future end-users and other stakeholders affected by the envisioned work process	Participation of pharmacy employees, supply chain manager from pharmaceutical company, system developers
Steps to perform	Select work process and points of view to investigate	Use of technology during incoming goods and at the point of dispense
	Collect information about work process	Interviews with developers, industry partners, pharmacist and pharmacy employees
	Construct narrative network of envisioned work process	First narrative network produced (see Table 4)
	Outline flexibility requirements, changing responsibilities and different points of view	Flexibility needs are outlined, such as, for example, cases when there are too many products delivered
	Decide on how to design work process	Discussion with developers and industry partners to define the usage scenario for the field trial
Data collection methods	Interviews, observation, documents	Interviews with stakeholders, written process description from the project
Results	Organisational work process, which takes into account changing responsibilities, flexibility requirements and different points of view	See narrative network in Table 4
		Adjustments made to the usage scenario, by adding some additional verification checks to the prototype and an order receipt step
Contribution to project	Development of sound usage scenario, including how the ubiquitous computing application is integrated in a work process	Support to reach a realistic trial set-up, including variations of work process
	Evaluation of prototype	Detailed process description for evaluation report (see Table 4)
Contribution to technology development	Identification of flexibility requirements	Fostering a debate about conflicting responsibilities for pharmacy employees when the verification technology is used at the point of dispense
	Resolve different points of view	Validation of incoming goods as potential point of future use for a verification technology

in future. Interviews should be conducted with these different stakeholders and other actors potentially affected by the implementation.

Second, the team member begins with collecting data via different methods, such as interviews, observation or documents describing the work process. Documents containing a process description can be used as a starting point, followed by interviews and, if possible, observations, which deliver a more detailed description. For interviews, the team member asks the interview partner to describe the work process in a step-by-step fashion, including possible variations in the sequence of actions.

Third, the team member can use the gathered process descriptions to construct a description of the envisioned work process, which is done in the form of a narrative network. The narrative network approach is a method proposed by Pentland and Feldman [62] to represent work processes. A narrative network is a collection of narrative fragments. The team member, therefore first needs to identify narrative fragments, which are combinations of actors and a functional event, such as, for example, "employee picks up parcel from the stock". Narrative fragments can include human actors and technological artefacts, which can substitute each other. For example, in the case of a ubiquitous computing application, where tracking data about the location of a product should always be available in a database, the updating of the data can be done manually by a person writing the information in a database or automatically by a reader that interrogates an RFID tag from a distance. Narrative networks are representations of potential and actual work processes in a sequence of action. Alternative sequences of action are possible and describe variations. A narrative network is constructed by relating identified functional events according to a sequence of action. Possible variations in the sequence of action are also outlined.

Fourth, the team member then uses the constructed narrative network to reflect on how to improve the envisioned work process of the ubiquitous computing application under development. The team member can compare the narrative network of the current work process with the envisioned work process according to the usage scenario to learn about missing sequences of action and common variations leading to requirements for flexibility. The team member also can elicit potential conflicts that may arise because of different points of view by stakeholders or because of mismatches between the envisioned and the current work process.

Fifth, such insights then can be used by all team members of the technology innovation project as a basis for decisions on how the ubiquitous computing application and envisioned usage scenarios could be adjusted. Decisions have to be taken, allowing flexibility or enforcing rigidity for workers involved in the work process. While flexibility has some benefits, like an ability to cope with variances or local optimisation, rigidity also has some benefits, like standardization and control that certain activities are performed in a proper way. In some cases, a rigid enforcement of sequence of action might be needed, due to, for example, safety reasons or compliance reasons. However, such decisions should be made explicit, keeping in mind the consequences of reducing variability and flexibility. In such cases, automation could be a preferred solution [62]. Before taking the decision, it is also useful to compare the different points of view and interests of stakeholders in flexible or rigid work processes.

5.1.4 When and where, by whom

The "work process tool" can be used as soon as a first usage scenario and process description of the ubiquitous computing application in a work environment is outlined. A team member is assigned as investigator, collecting different points of view and analysing them for the project.

5.1.5 Application of the "work process tool" in a pharmacy

To show the application of the tool, we refer to findings from the envisioned usage of the ubiquitous computing application for incoming goods in the pharmacy (see also Fig. 2). We collected narrations through interviews. Developers and industry partners were asked to indicate the actors involved and describe the envisioned processes step by step. Supervisors of the work system were asked to describe the work process, including its variations and disturbances. Trial participants at the pharmacy were asked to describe their current work processes. We were able to construct the narrative network outlined in Table 4. The outlined work process is about how incoming goods are handled at the moment. It appeared that there are some variations in the sequence of actions, for example, if the employee discovers that too many products have been ordered, suddenly the pharmacist is involved. This leads to a variation in the work process. The pharmacist may, for example, use the enterprise resource planning system (ERP) to learn about the past sales and then decide either to keep the extra drugs or send them back. Based on his decision, the pharmacy assistant then performs the follow-up steps in the work process, such as sending the product back or putting it into stock.

The findings on the current work process were used to derive requirements for functions of the software infrastructure and to make some adaptations to the usage scenario. The first usage scenarios discussed by team members in the project focused on the verification of an incoming good without considering additional issues that might lead to a variation in the work process. We therefore changed and extended the originally envisioned work process of the project, by including an order receipt and adding an additional check for due dates. This contributed to the project because a more realistic usage scenario was used to test the prototype during the application trial.

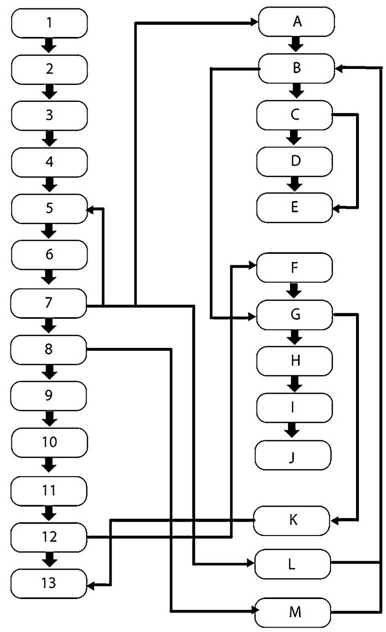
5.2 "Work system tool"—aligning a ubiquitous computing application with the affected work system and taking work realities into account

5.2.1 Introduction and tool criteria

The "work system tool" helps team members to align the ubiquitous computing application and the work system. For this, a team member looks at the primary task of the work system under study, and assesses how the ubiquitous computing application may change the system, and how the three KOMPASS criteria of a well-designed work system are affected.

First, the criterion completeness of the work task describes the degree of functional integration of parts of the production or service process. This criterion is used to assess whether a new ubiquitous computing application may increase or decrease the completeness of work tasks. Generally, it appears advisable to increase the completeness of a work task as this allows employees to locally control variances and disturbances [35]. Better completeness of a work task allows local control of variances or disturbances. The second criterion is the independence of the work system. This criterion describes how and if variances or disturbances occurring in other work systems impact on the work system under study. We look at how a work system would become more or less dependent on other work systems. The third criterion describes the fit between regulation requirements (i.e. many uncertainties) and regulation opportunities (i.e. cooperation form) of a work system. An investigator evaluates whether the fit would be changed by the ubiquitous computing application and how misalignments can be avoided. Table 5 provides an overview of the tool.

Table 4 View of a work process as a narrative network

Narrative fragments of work process goods delivery	Network view on work process	Variations of events
1. Wholesaler delivers pharmaceutical product to pharmacy 2. Employee takes order receipt 3. Employee types in order number into the system 4. System displays order 5. Employee scans barcode of a delivered pharmaceutical product category 6. System tells employee about ordered amount 7. Employee compares amount available with amount needed 8. Employee manually adds due date for each product and how to store the product into own ERP system 9. Employee fills out order sheet 10. Employee puts order sheet in folder 11. Pharmacist checks the order and the bill 12. Pharmacist looks at the delivered products 13. Employee puts product on general stock or products preorder by a client to special place for preordered product		*Missing product* A. Employee sees that not enough products are delivered B. Employee informs pharmacist about issue C. Pharmacist looks at pending orders, to know how important a delivery is D. Pharmacist contacts wholesaler to learn about the delivery date E. Pharmacist issues an order to get the product *Too many products* F. Pharmacist detects that too many products were ordered G. Pharmacist checks in the system, to learn how many they usually need H. Pharmacist decides to send back some products I. Employee fills out a return shipment form J. Employee sends back the products *Additional pathways* K. Pharmacist decides to keep product L. Employee sees that too many products are ordered M. Employee sees that the due date is too short

5.2.2 Scope, purpose, benefits of use and outcome

The tool can be used for almost any ubiquitous computing application used in a work system. The tool can be used for different types of large work system; however, the boundaries of the work system need to be clear. The purpose of the tool is to gather knowledge about an existing work system; to collect requirements for the ubiquitous computing application and to understand the potential impact on predefined criteria of a work system.

The potential benefit is having a structured approach to learn about the potential impact of the ubiquitous computing application on a work system, due to the selection of certain important criteria of relevance for a well-designed work system. By providing input for the application trial, the tool also allows the performance of more realistic trials by supporting task descriptions for trial users and having better test cases for activities that can only be simulated.

The outcome is a more detailed description of the work system for which the ubiquitous computing application is intended, a listing of expected changes to the work system through the ubiquitous computing application and of needed changes for the ubiquitous computing application to improve its alignment with a work system.

5.2.3 Description of how to use the "work system tool"

As a prerequisite, usage scenarios are necessary that describe in which work systems the ubiquitous computing application would be used, and what for. The work process tool is of particular help in identifying and selecting the work system to analyse.

First, a semi-structured interview guideline for a workplace interview with the supervisor and an observation guideline for a short observation are used to collect information. Needed is an overview of the work system, an assessment of the outlined KOMPASS criteria, a list of primary and other important work tasks, a description of the surrounding organisation and a list of major variances and disturbances. In a second step, the information can then be used to assess the rating of the three KOMPASS criteria in the current system. In a third step, together with other

Table 5 "Work system tool": summary and illustration

	Description	Example: distribution centre
Scope and purpose	Gather knowledge about a work system, collect requirements for ubiquitous computing application and assess positive and negative impact on the self-regulation of the work system	Integration of a verification technology in a distribution centre for luxury goods
Prerequisites	Work system	Distribution centre of luxury goods provider
	Participation of supervisor of work system	Supervisor and supply chain manager
Steps to perform	Interview with supervisor to collect information	Interview in distribution centre
	Assess rating of three KOMPASS criteria	Discussion with supervisor, industry partner and developer about the impact of the ubiquitous computing application on the work system
	Prospective assessment on how ubiquitous computing application might change rating	
	Develop strategies, how to improve alignment	Decide trial set-up with team members
Data collection methods	Semi-structured interview, short observations	Interviews with supervisor of the work system and short observations
Results	Detailed description of the work system, expected changes to the work system and needed alignments between work system and ubiquitous computing application	No effect on task completeness
		Higher dependency due to ubiquitous computing applications functioning
		Lacking regulation opportunities in case of an incident
Contribution to project	Recommendations to adjust usage scenario, prototype and work system to improve their alignment and to have a realistic trial set-up	Support to reach a realistic trial set-up in the distribution centre and support the selection of adequate place and persons of use
	Contribution to the evaluation report on the fit of technology to work system	
Contribution to technology development	Recommendations for aligning work system and technology	Recommendations on how to solve the incident handling in case of a counterfeit for future application guidelines

team members or if possible with the supervisor, a prospective assessment can be made of how the new ubiquitous computing application relates to the main task and how it might change the criteria of a well-designed work system. In a fourth step, the results should be discussed and strategies developed on how to address misalignments between the primary work task and newly introduced tasks. If the ubiquitous computing application has a negative impact on the rating of the three criteria, team members need to think about how the ubiquitous computing application or usage scenario could be changed. Team members should also reflect on strategies for using their ubiquitous computing application to support the fulfilment of the work system's main task. Also they could reflect how the ubiquitous computing application might contribute to a well-designed work system. Findings can then be used to adjust the usage scenario and the prototype, and can be disseminated with application guidelines.

5.2.4 When and where, by whom

The tool can be used after team members have identified a work system where the envisioned ubiquitous computing application should be used in future. The interviews should be conducted at the identified work site with the supervisor of the work system. Ideally, the tool is used a certain time before the trials since this will allow adjustments to be made to the ubiquitous computing application in advance. A team member can conduct the interviews based on the proposed guidelines and following the described steps for analysis.

5.2.5 Application of the "work system tool" at the distribution centre

We shall use findings from the real-world application trial in the distribution centre of a luxury goods manufacturer to illustrate the application of the tool. Because the proposed ubiquitous computing application would currently only add one verification step for each product, it became clear that not many changes would arise at the work system level, and most ratings of the KOMPASS criteria would be only slightly changed. Having a safe supply chain was also of importance and in line with the main tasks. The completeness of the work system's task was not affected, because in all cases, verifications of the genuineness of products were not part of the work system before. Instead, the independence of the work system was affected because the work systems became dependent on an external verification solution. The supervisor and employees pointed out that the packing operation is time critical during certain periods of the year. They needed to send out the new collections to the stores within a very narrow timeframe. During such periods, supervisors and employees depend on a fast and reliable system and do not want to be blocked by technical difficulties. As a result, technical reliability issues would make it hard for the employees to use such a system and backup strategies would be needed. The fit between regulation requirements and regulation opportunities was also identified as a critical issue that needs to be addressed. The main issue was the lack of regulation opportunities required in the case of a counterfeit incident. Basically it became clear that in such a case, procedures need to be specified and responsibilities of the work system clarified so the system can react properly. The collected information was used for the definition of the test cases for the trials and provided a more realistic environment for test users. The need for the definition of clear procedures in case of an incident became part of the application guidelines.

5.3 "Human controllability tool"—maintaining appropriate human control and aligning individual work activities

5.3.1 Introduction and tool criteria

The "human controllability tool" addresses issues of human–computer interaction, focussing on maintaining human control over technical systems and improving the intelligibility of a ubiquitous computing application's actions. In addition, the tool looks at the alignment with existing individual work activities, including the perceptions of future employees using the system about its usefulness for their work.

For the "human controllability tool", control is understood as an actor's ability to influence conditions and processes in a chosen manner leading to the outcome intended by the actor. Prerequisites for control are transparency, predictability and sufficient influence over process and outcome [37]. Transparency and predictability address issues of understanding about the functioning of a ubiquitous computing application. Sufficient influence means that an actor needs to have the appropriate means, such as tools and resources, and decision authority to be able to influence the outcome as intended by him or her.

Even minor misalignments between work activities performed by an actor and changes with the introduction of a ubiquitous computing application might lead to challenges for organisations, for example, unwanted circumventions or disruptions of individual work activities [46]. To investigate such potential misalignments, the situation of use is analysed by interviewing trial participants in their work environment. In addition, the perception of the technological solution by prospective employees is taken into account, as this might give initial clues on potential issues that might arise with the introduction of the technology. Table 6 provides an overview of the tool.

5.3.2 Scope, purpose, benefits of use and outcome

The tool is for testing a ubiquitous computing application with prospective users in their work environment. The purpose is to assess and evaluate human-centred issues during a so-called real-world application trial. The potential benefit of use is that it will give a structured evaluation of human control capabilities, guidance on how to increase individual self-regulation, and provide qualitative input from prospective users on the alignment of the solution with their work activities, including their views on benefits and risks.

The outcome is an evaluation of the ubiquitous computing applications on controllability and alignment with existing work activities. The results of the evaluation can be used to improve the ubiquitous computing application or to provide recommendations for the further development of similar ubiquitous computing applications.

5.3.3 Description of how to use the "human controllability tool"

The prerequisite is a real-world application trial with future end-users. The trial set-up should be as realistic as possible. The list of actors from the "work process tool" can be used to identify possible employees for testing the prototype and applying the "human controllability tool". Outputs from the "work system tool" can be used to define the tasks to comply with the new system and to simulate the context of use. The tool is used during the performance of the field trials.

The first step therefore is to organise a trial with future end-users willing to test the technology in their work environment. The second step is then to perform the trial with future end-users and to gather data through observation, questionnaires and semi-structured interview guidelines after each user has performed the trial. The third step is to analyse the collected data, to learn about critical human-centred issues. Basically, the fulfilment of the predefined criteria on human control and alignment with work activities is assessed. This, then, can be discussed with the project team members to decide how the prototype or usage scenario could be adjusted to eliminate critical human-centred issues. The outputs can be used for an evaluation, namely to assess how well certain criteria are fulfilled, or to describe in the application guidelines human-centred issues that need to be addressed in future to avoid challenges for organisations.

Table 6 "Human controllability tool": summary and illustration

	Description	Example: distribution centre
Scope and purpose	To assess and evaluate the controllability and alignment of a ubiquitous computing application with the work activities of a prospective user	Evaluation of the developed prototype by prospective end-users. Testing the developed prototype during the packing of goods by workers
Prerequisites	Working prototype or mock-up	Prototype of PVI infrastructure
	Access to a work environment	Participation of a distribution centre
	Participation of workers	Participation of workers of the distribution centre
Steps to perform	Organise trial with future end-users	Organised by the project in a distribution centre
	Perform trial and evaluation	Two trial rounds at the distribution centre
	Assess controllability and alignment with work activities	Between the first and second trial, several adjustments were made to improve the intelligibility of the reading of RFID tags
	Take needed measures to increase controllability and improve alignment with work activities	
Data collection methods	Structured interviews and observation	Interviews and observation of workers in the distribution centre
Results	Description on how ubiquitous computing application constrains or enables human controllability	Lacking predictability of reading of RFID tags from distance
	Evaluation of alignment between existing work activities and newly introduced ones	Need to define incident handling by employees
		Low importance attributed to verification of counterfeits by employees
Contribution to project	Improved human controllability of prototype	Improved predictability of reading of RFID tags by prototype
	Improved alignment with existing work activities	Identification of lacking controllability of reading of multiple packages at once
	Provision of an evaluation about the controllability of the prototype and its alignment with existing work activities	Alignment of a new verification activity with existing work activities of employees
Contribution to technology development	Recommendations on how to maintain human controllability and how to align with existing work activities for the application guideline	Recommendations in application guideline on incident handling and need for awareness raising about danger of counterfeits
		Recommendations on how to improve controllability of RFID readers

5.3.4 When and where, by whom

The tool is used during the first trials of prototypes or mock-ups with possible future end-users. Team members use the interview guidelines. The questionnaire is given after the end-users have used the prototype to fulfil some work activities. If there are several iterative trials, team members can use the tool again and compare the results.

5.3.5 Application of the "human controllability tool" at the distribution centre

A preliminary version of the tool was applied in all application trials of the SToP project. A major issue of a lack of human control over the ubiquitous application was identified during the performance of the trials in the distribution centre. In the distribution centre, the technology was tested while goods were being packed for delivery. At this stage of the work process, employees pack goods according to a packing list into a delivery box and make them ready for delivery. This includes the sequence of taking products from the storage area, scanning the products' barcode, putting them into a delivery box, closing the box, weighing the box, printing out the delivery address and finally, moving the box onto a conveyor belt. The ubiquitous computing application was envisioned to replace the scanning of the product barcode with an antenna scanning for RFID tags in an outlined reader field. To make the packing process more efficient, one idea was to allow the scanning of multiple RFID-enriched products at once. We were able to observe and get feedback from employees on the lack of control capabilities. The employees did not feel that they had enough control over what was read and not read by the RFID reader. The employees' main problem was the unpredictable behaviour of the RFID reader due to the reading range and lack of knowledge about how RFID systems function. Sometimes the system displayed that an item had just been read although an employee only picked up the item without intending to read it. Employees also temporarily stored several packages right next to the reader and those packages got accidentally scanned. The employees were used to picking several packages from the stock in order to read them one by one and to reduce the time spent walking to and from the stock storage area. The employees tried to cope with the reading problem with ad hoc solutions that did not work. For example, some employees held a product behind their back, hoping that their own bodies would act as a shield against the reader's field. Obviously, employees′ understanding of the functioning of the technology was incorrect. Although shielding the formerly used barcodes may prevent a laser reading the barcode, wireless transmissions cannot be shielded in the same way. Reading the RFID chips of multiple packages at once was difficult to handle. Employees were unsure how to identify counterfeits when multiple items were read at the same time. In the case of single reading, employees felt they could control better what was or was not read. For the trial evaluation and for the application guidelines, the project concluded that having the right reading range was a key issue for a successful deployment. On the one hand, a long reading range allows employees to scan items from a certain distance without needing to orient the tag towards the reader or to hold the package very close to the reader. On the other hand, an excessively long reading range detects packages that should not have been read, leading to low controllability.

In the distribution centre, barcodes of products were commonly scanned, but still a new work activity became necessary. The new work activity was the adding of a verification step during the scanning of the product and the replacement of product barcodes with unique identification codes and an RFID tag. Employees at the distribution centre were not familiar with quality control issues, and only focused on packing and shipping as fast as possible. A critical issue was that counterfeit checks are different to the current packing list checks. In the case of a wrong product, an employee simply replaces the product. This would not work for counterfeits. In the case of a counterfeit, the incident handling process is substantially more complex since it requires the involvement of another department and leads to an investigation. In the application guidelines, it was therefore recommended that the different handling of incidents should be taken into account and addressed. A proposed technical solution, which employees also agreed with, was to block the system in the rare event of a counterfeit and then provide guidance to the employee about the next steps.

The interviews also gave some insights into the perception of the usefulness of the proposed ubiquitous computing application. In general, employees had some doubts about the importance of a ubiquitous computing-based anti-counterfeiting system for their workplace. In particular, none of the trial participants knew about counterfeiting issues at their workplace. Though the employees generally agreed that counterfeits are a problem in the industry, they did not think that counterfeit products would show up at their workplace, but rather thought that they were a problem resulting from sales over the Internet. As a result of the project, it was proposed in the application guidelines, that there was a need to raise awareness about the danger of counterfeits also in law-abiding locations, such as distribution centres.

6 Discussion

Ubiquitous computing applications will have a discernible impact on organisations. On the one hand, they may have benefits, such as increased operational performance. On the other hand, disturbances might occur due to misalignments between ubiquitous computing applications, tasks and users. It is a challenge to predict organisational issues during the early stage of technology development. The presented toolbox addresses this challenge. In particular, the toolbox supports the analysis of potential organisational issues by team members of a technology innovation project on three levels of a socio-technical system; that is, the work process, the work system and the individual. The "work process tool" supports the description of envisioned work processes. In particular, it supports the gathering of flexibility and variability requirements, the identification of changing responsibilities and eliciting differences between points of view of different stakeholders about an envisioned work process. The "work system tool" analyses the alignment of a proposed ubiquitous computing application and a self-regulated work system. In particular, changes to task completeness, independence and the fit between regulation requirements and regulation opportunities are assessed. The "human controllability tool" allows analysis of how an individual worker's control capability to fulfil his responsibilities are enabled or constrained with the new ubiquitous computing application. While the criteria for each tool are distinct, a potential change to a criterion might also affect other elements of the socio-technical system. For example, some elements of the "human controllability tool" interact with the "work system tool". Many individual work activities are dependent on the main task of the work system under study. Changes on the work system level therefore affect the individual level, and vice versa. For example, the procedure outlined for incident handling if a counterfeit is identified in a work system subsequently defines the activities of an individual employee, including the required control capabilities. Changes to the work process also affect the work system and individual level. The work process, for example, defines in which work system verification is done. However, results from the individual level might also affect the work process if an assigned responsibility cannot be satisfied by an individual worker due to a lack of control capabilities, and therefore, this would lead to a change in the work process.

6.1 Critical assessment of toolbox for managing organisational issues

We critically assess the outlined tools of our toolbox by discussing how the requirements described in the previous sections are met. The toolbox qualifies as a socio-technical systems design approach, in that it allows systematic analysis of different levels of a socio-technical system and of the interplay between levels. The criteria of the different tools are built on socio-technical principles. In particular, all three tools aim for self-regulation on the work system level (i.e. "work system tool" and "work process tool") and the individual level (i.e. "human controllability tool" and "work process tool"). The "human controllability tool" also supports the establishment of motivating work tasks. The identification of conflicting points of view—which is part of the "work process tool"—also allows political issues to be explicitly addressed in organisations and fosters debates about choices and their consequences for responsibilities [cf. 16]. The fulfilment of the requirement to have a toolbox for an early stage technology innovation project is shown, as we were able to use the toolbox successfully for the SToP project. Also, the toolbox is applicable for ubiquitous computing technologies. The project participants and reviewers of the project regarded the debates based on the findings as useful and beneficial to the aims of the research project. For example, the issue of the lack of control capabilities to detect a counterfeit if multiple items are read at once was taken up at later stages of the project. The requirement of applicability for people without detailed knowledge of organisational issues has only been met partially, because so far, only the first author of the paper has used the toolbox. However, the project team members reviewed the guidelines and one of them used them for a small trial inside the project. The provision of tangible guidance for the further development of the ubiquitous computing application or as part of application guidelines was met several times, for example, in the case of changes to the envisioned work process or by adding information on organisational issues to the application guidelines. As the individual criteria of the different tools build on already tested and validated criteria based on other research, we did not validate them again in this project.

6.2 Relation to existing approaches

Ethnographic approaches [17], in situ evaluation [20], cost and benefit analysis [3], privacy assessment tools [29], participatory design approaches [13] and new human–computer interaction approaches [7] already address some organisational issues of ubiquitous computing projects in the early stage of development. However, most of the above-mentioned approaches focus on quite a small subset of organisational issues. Our toolbox partially builds on some of these approaches, but also adds a new perspective on organisational issues by building a toolbox with principles of socio-technical design in mind [16]. Therefore, our approach is broader as it addresses different levels, such as work system, individual work and work processes. For all of those aspects, the corresponding tools allow potential organisational issues to be investigated and either help users to decide on how to change the design or offer input for dissemination activities. We provide means to address human-centred issues. Differing from ethnographic approaches, our "human controllability tool" explicitly builds on the concept of human control capabilities, including the alignment with other work activities, but puts less emphasis on the whole context of use. Also, with our criteria, we not only provide a description but also an assessment on how, for example, the self-regulation of a work system is affected. This includes guidance on how to improve the rating if needed. Unlike human–computer interaction approaches [7], the "human controllability tool" focuses not only on the interaction with the ubiquitous computing application, but more generally on the control capabilities needed by an actor to fulfil his responsibilities. Our tool covers some organisational issues not yet covered by existing approaches in the domain of ubiquitous computing. The "work process tool" covers variations and flexibility requirements when re-designing work processes. The "work system tool" is an attempt to provide a tool for managing the organisational contribution and organisational alignment issues of a work system in the domain of ubiquitous computing. In general, the presented tools emphasise an alignment view, aiming to guarantee optimal alignment between individual work, work system, work processes and ubiquitous computing technologies. In comparison to participatory design approaches, we only partially address the participation of stakeholders in the design process. We mainly increase the involvement of stakeholders by using them as informants for the analysis of our criteria and expect them to be team members of the technology innovation project.

6.3 Implications

Organisational issues matter in the development of ubiquitous computing applications and technology innovation projects need to look beyond questions of privacy, human–computer interaction, economic cost and benefit analysis and societal impact. Design approaches and approaches for addressing organisational issues should also consider additional organisational issues, such as the impact on work processes, the work system or human control capabilities.

In addition, such tools also should try to overcome their restricted use by involved researchers for the description of the deployment of ubiquitous computing applications or for the evaluation of a prototype at the end of a project [27]. Instead, based on such tools, researchers should be able to make specific design decisions and have the appropriate means to actually integrate findings on potential organisational issues in outputs of research projects, such as deliverables for stakeholders.

Our findings also have some implications for early stage technology innovation projects. Our toolbox provides some guidance in how to deal with organisational issues in an early stage of technology innovation by either adjusting the prototype, including usage scenarios, or by developing application guidelines for the further development of the technology innovation. Early stage technology innovation projects need to expand their view and address organisational issues more explicitly because decisions made in an early stage of technology innovation have an impact on whether, how and which organisational issues arise in a later stage or during implementation [39, 48]. Dealing with organisational issues at an early stage goes in line with other calls for increasing the accountability of such projects beyond the mere development of a technological solution and testing its technological feasibility, but also for the later use of the ubiquitous computing application in organisations [cf. 10, 11, 37, 74].

6.4 Limitations

Predictions about the future of work and organisational issues due to ubiquitous computing are difficult, especially if deployments are several years ahead and it is highly likely that many changes to the envisioned ubiquitous computing application will be made. Such changes also affect potential organisational issues. In addition, as several studies of other information technologies have shown, the enactment of the technology in the situation of use might provoke new and unexpected organisational issues [62]. For example, the implications for users' working style only might become visible after a certain period of use, when the worker is confronted with different challenges. However, this is not only a limitation of our toolbox for managing organisational issues, but also holds true for other predictions, such as market predictions or cost and benefit analyses. Still, considerable benefits, such as improving the alignment between existing work systems, individual work tasks or work processes and an envisioned ubiquitous computing application, justify the use of the tool in early stages of technology innovation projects.

Another limitation of our toolbox is that it was mainly built and tested in one ubiquitous computing project, which focuses on process orientation and on the management of goods. We showed the applicability of our toolbox for such an application. However, many more ideas and visions exist about using ubiquitous computing in work environments without a focus on process orientation. While we assume that our toolbox might also be valuable for these other environments, due to the current limited application and the novelty of the approach, it is difficult to outline its applicability in detail for other ubiquitous computing applications.

6.5 Conclusion

In conclusion, based on socio-technical design ideas, we developed a toolbox for managing organisational issues of ubiquitous computing applications and applied the toolbox during the early stage of technology innovation. In doing so, we responded to calls for applying socio-technical design approaches also in the domain of ubiquitous computing applications [cf. 69]. The tools support project team members in dealing with organisational issues of a ubiquitous computing application during the early stage of technology innovation; thereby, it becomes more likely that changes triggered by the application on the organisation are desirable [cf. 23]. The toolbox provides guidance on how to change the design of a ubiquitous computing application and how to improve the envisioned usage scenario or derive application guidelines and recommendations. Finally, the results of our case study demonstrate the applicability of our approach for early stage technology innovation projects in the domain of ubiquitous computing.

Acknowledgments This research was funded by the ETH Research Grant TH -31/06-1 and the EU funded project SToP (Stop Tampering of Products (IST-034144)). We also thank Mikko Lehtonen, Harald Vogt, Ali Dada, Nina Oertel, Jens Müller, Katharina Kinder-Kurlanda and Johann Weichbrodt for their support and comments.

References

1. Abowd G, Mynatt E (2002) The human experience. IEEE Pervasive Comput 1(1):48–57
2. Axtell C, Pepper K, Clegg C, Wall T, Gardner P (2001) Designing and evaluating new ways of working: the application of some socio-technical tools. Hum Factors Ergon Manuf 11(1):1–18
3. Baars H, Gille D, Struecker J (2009) Evaluation of RFID applications for logistics: a framework for identifying, forecasting and assessing benefits. Eur J Inf Syst 18(6):578–591
4. Barkhuus L, Dey A (2003) Is context-aware computing taking control away from the user? Three levels of interactivity examined. In: Dey A, Schmidt A, McCarthy JF (eds) UbiComp 2003 ubiquitous computing: lecture notes in computer science. Springer, Berlin, pp 149–156

5. Barley S (1986) Technology as an occasion for structuring. Adm Sci Q 31:78–108
6. Bellotti V, Edwards K (2001) Intelligibility and accountability: human considerations in context-aware systems. Hum Comput Interact 16(2):193–212
7. Benford S, Schnödelbach H, Koleva B, Anastasi R, Greenhalgh C, Rodden T, Green J, Ghali A, Pridmore T, Gaver B, Boucher A, Walker B, Pennington S, Schmidt A, Gellersen H, Steed A (2005) Expected, sensed, and desired: a framework for designing sensing-based interaction. ACM Trans Comput Hum Interact 12(1): 3–30
8. Bohn J, Coroama V, Langheinrich M, Mattern F, Rohs M (2004) Living in a world of smart everyday objects—social, economic, and ethical implications. J Hum Ecol Risk Assess 10(5):763–786
9. Boos D, Günter H, Grote G (2007) Organisational issues, technological frames and the development of a new ubiquitous computing application. In: 23rd EGOS colloquium, 5–7 July 2007 Vienna (Open subtheme: from ballroom dance to improvisation: complementary dances in organisation studies). EGOS, Berlin
10. Boos D, Grote G (2012) Controllable accountabilities: the Internet of things and its challenges for organisations. Behaviour and Information Technology, iFirst
11. Boos D, Grote G (2012) Designing controllable accountability of future internet of things applications. Scand J Inf Syst 24(1):3–28
12. Bose I, Ngai EWT, Teo TSH, Spiekermann S (2009) Managing rfid projects in organisations. Eur J Inf Syst 18(6):534–540
13. Büscher M, Christensen M, Hansen KM, Mogensen P, Shapiro D (2007) Bottom-up, top-down? connecting software architecture design with use. In: Voss A, Hartswood K, Ho K, Procter R, Rouncefield M, Slack R, Büscher M (eds) Configuring user-designer relations: interdisciplinary perspectives. Springer, Berlin
14. Boudreau MC, Robey D (2005) Enacting integrated information technology: a human agency perspective. Organ Sci 16(1):3–18
15. Clegg CW, Coleman P, Hornby P, McClaren R, Robson J, Carey N (1996) Tools to incorporate some psychological and organisational issues during the development of computer-based systems. Ergonomics 39(3):482–511
16. Clegg CW (2000) Sociotechnical principles for systems design. Appl Ergon 31:463–477
17. Crabtree A, Rodden T (2002) Ethnography and design? In: Proceedings of the international workshop on "interpretive" approaches to information systems and computing research. London, Association of Information Systems, pp 70–74
18. Crabtree A, Rodden T, Tolmie P, Button G (2009) Ethnography considered harmful. In: Olsen DR, Arthur RB (eds) Proceedings of the 27th international conference on human factors in computing systems (CHI '09). ACM, New York, pp 879–888
19. Cooper RG (1996) Overhauling the new product process. Ind Mark Manag 25(6):465–482
20. Consolvo S, Harrison BL, Smith IE, Chen MY, Everitt K, Froehlich J, Landay JA (2007) Conducting in situ evaluations for and with ubiquitous computing technologies. Int J Hum Comput Interact 22(1):103–118
21. Davies N, Gellersen H-W (2002) Beyond prototypes: challenges in deploying ubiquitous systems. IEEE Pervasive Comput 1(1): 26–35
22. Doherty NF, King M (1998) The consideration of organisational issues during the system development process: an empirical analysis. Behav Inf Technol 17(1):41–51
23. Doherty NF, King M (2001) An investigation of the factors affecting the successful treatment of organisational issues in systems development projects. Eur J Inf Syst 10(3):147–160
24. Doherty NF, King M (2005) From technical to socio-technical change: tackling the human and organisational aspects of systems development projects. Eur J Inf Syst 14(1):1–5
25. Doherty NF, King M, Al-Mushayt O (2003) The impact of inadequacies in the treatment of organisational issues on information systems development projects. Inf Manag 41(1):49–62
26. Dourish P (2004) Where the action is: the foundations of embodied interaction. MIT Press, Cambridge
27. Dourish P (2006) Implications for design. In: Grinter R, Rodden T, Aoki P, Cutrell E, Jeffries R, Olson G (eds) Proceedings of the SIGCHI conference on human factors in computing systems (CHI '06). ACM, New York, pp 541–550
28. Eason K (2001) Changing perspectives on the organisational consequences of information technology. Behav Inf Technol 20(5):323–328
29. EPTA (2006) ICT and privacy in Europe: experiences from technology assessment of ICT and Privacy in seven different European countries. Final report 2006: European Parliamentary Technology Assessment. http://epub.oeaw.ac.at/0xc1aa500d_0x0013038d.pdf. Accessed 7 April 2011
30. Feldman MS, Pentland BT (2003) Reconceptualizing organisational routines as a source of flexibility and change. Adm Sci Q 48(1):94–118
31. Fleisch E (2004) Business impact of pervasive technologies: opportunities and risks. Hum Ecol Risk Assess 10(5):817–829
32. Fleisch E, Mattern F (eds) (2005) Das Internet der Dinge: Ubiquitous Computing und RFID in der Praxis: Visionen, Technologien, Anwendungen, Handlungsanleitungen. Springer, Berlin
33. Fleisch E, Tellkamp C (2006) The business value of ubiquitous computing technologies. In: Roussos G (ed) Ubiquitous and pervasive computing. New frontiers for electronic business. Springer, London
34. Grote G, Weik S, Wäfler T, Zölch M (1995) Criteria for the complementary allocation of functions in automated work systems and their use in simultaneous engineering projects. Int J Ind Ergon 16:367–382
35. Grote G, Ryser C, Wäfler T, Windischer A, Weik S (2000) KOMPASS: a method for complementary function allocation in automated work systems. Int J Hum Comput Stud 52(2):267–287
36. Grote G, Weichbrodt JC, Günter H, Zala-Mezö E, Künzle B (2009) Coordination in high-risk organisations: the need for flexible routines. Cogn Technol Work 11:17–27
37. Grote G (2009) Management of uncertainty: theory and application in the design of systems and organisations. Springer, London
38. Günter H, Grote G, Boos D (2006) Organisational issues in ubiquitous computing. In: 27nd EGOS colloquium, 6–8 July 2006 Bergen (Subtheme 14: Technology, Organisation and Society: Recursive Perspectives). EGOS, Berlin
39. Heller T (2000) If only we'd known sooner: developing knowledge of organisational changes earlier in the product development process. IEEE Trans Eng Manag 47(3):335–344
40. Hilty LM, Som C, Koehler A (2004) Assessing the human, social and environmental risks of pervasive computing. J Hum Ecol Risk Assess 10(5):853–874
41. Kapoor G, Zhou W, Piramathu S (2009) Challenges associated with rfid tag implementations in supply chains. Eur J Inf Syst 18(6):526–533
42. Kern C (2004) Radio-frequency-identification for security and media circulation in libraries. Electron Libr 22(4):317–324
43. Kinder K (2009) Ubiquitous computing in industrial workplaces: cultural logics and theming in use contexts. Lancaster University, Dissertation
44. Kinder K, Ball LJ, Busby JS (2008) Ubiquitous technologies, cultural logics and paternalism in industrial workplaces. Poiesis Praxis Int J Technol Assess Ethics Sci 5(3–4):265–290
45. Kjeldskov J, Skov M (2007) Exploring context-awareness for ubiquitous computing in the healthcare domain. Pers Ubiquit Comput 11(7):549–562

46. Konomi S, Roussos G (2007) Ubiquitous computing in the real world: lessons learnt from large scale rfid deployments. Pers Ubiquit Comput 11(7):507–521
47. Koops B-J, Hildebrandt M, Jaquet-Chiffelle D-J (2009) Bridging the accountability gap: rights for new entities in the information society? ExpressO. http://works.bepress.com/bert_jaap_koops/3. Accessed 7 April 2011
48. Kortuem G, Alford D, Ball L, Busby J, Davies N, Efstratiou C, Finney J, White M, Kinder K (2007) Sensor networks or smart artifacts? an exploration of organisational issues of an industrial health and safety monitoring system. In: Krumm J, Abowd GD, Seneviratne A, Strand T (eds) UbiComp 2007: ubiquitous computing. Springer, Berlin, pp 465–482
49. Lahlou S, Langheinrich M, Roecker C (2005) Privacy and trust issues with invisible computers. Commun ACM 48(3):59–60
50. Langheinrich M (2005) Personal privacy in ubiquitous computing—tools and system support. Dissertation, ETH Zurich
51. Lee JD (2006) Human factors and ergonomics in automation design. In: Salvendy G (ed) Handbook of human factors and ergonomics, 3rd edn. Wiley, New Jersey, pp 1570–1596
52. Luff P, Hindmarsh J, Heath C (2000) Workplace studies: recovering work practice and informing system design. Cambridge University Press, New York
53. Lyons MH, Potter JMM, Holm DAM, Venousiou R, Ellis R (2004) The socio-economic impact of pervasive computing—intelligent spaces and the organisation of business. BT Technol J 22(3):27–38
54. Lyytinen KJ, Yoo Y (2002) Research commentary: the next wave of nomadic computing. Inf Syst Res 13(4):377–388
55. Lyytinen KJ, Yoo Y (2002) Issues and challenges in ubiquitous computing. Commun ACM 45(12):63–65
56. Lyytinen KJ, Yoo Y, Varshney U, Ackerman M, Davis G, Avital M (2004) Surfing the next wave: design and implementation challenges of ubiquitous computing. Commun AIS 40(13):697–716
57. Maron PJ, Minder D, Embedded WiSeNts Consortium (2006) Embedded WiSeNts research roadmap. Logos-Verlag, Berlin
58. Mattern F, Sturm P (2003) From distributed systems to ubiquitous computing—the state of the art, trends, and prospects of future networked systems. In: Irmischer K, Fähnrich KP (eds) Conference proceedings der Fachtagung Kommunikation in Verteilten Systemen. Springer, Berlin
59. Mumford E (1996) Systems design: ethical tools for ethical change. Palgrave Macmillan, London
60. Norman D (2007) The design of future things. Basic Book, New York
61. Orlikowski WJ (2000) Using technology and constituting structures: a practice lens for studying technology in organisations. Organ Sci 11(4):404–428
62. Pentland BT, Feldman MS (2007) Narrative networks: patterns of technology and organisation. Organ Sci 18(5):781–795
63. Pentland BT, Haerem T, Derek W, Hillison DW (2007) Using Workflow Data to Explore the Structure of an Organisational Routine. In: Becker MC, Lazaric N (eds) Organisational routines. Advancing empirical research. Edward Elgar Publishing, London
64. Pentland BT, Feldman MS (2008) Designing routines: on the folly of designing artifacts, while hoping for patterns of action. Inf Organ 18(4):235–250
65. Ramchand A, Devadoss PR, Pan SL (2005) The impact of ubiquitous computing technologies on business processes and change and management: the case of Singapore's national library board. In: Sorenson C, Lyytinen K, Yoo Y, DeGross J (eds) Designing ubiquitous information environments: socio-technical issues and challenges. Springer, Berlin, pp 149–152
66. Robey D, Boudreau M-C (1999) Accounting for the contradictory organisational consequences of information technology: theoretical directions and methodological implications. Inf Syst Res 10(2):167–185
67. Roussos G, Kostakos V (2009) RFID in pervasive computing: state-of-the-art and outlook. Pervasive Mob Comput 5(1):110–131
68. Parasuraman R, Riley V (1997) Humans and automation: use, misuse, disuse, abuse. Hum Factors Ergon Soc 39(2):230–253
69. Sorensen C, Yoo Y, Lyytinen K, DeGross JI (eds) (2005) Designing ubiquitous information environments: socio-technical issues and challenges. Springer, New York
70. Spiekermann S, Pallas F (2006) Technology paternalism—wider implications of ubiquitous computing. Poiesis Praxis Int J Ethics Sci Technol Assess 4:6–18
71. Spiekermann S (2008) User control in ubiquitous computing: design alternatives and user acceptance. Shaker Verlag, Aachen
72. Spiekermann S, Langheinrich M (2009) An update on privacy in ubiquitous computing. Pers Ubiquit Comput 13(6):389–390
73. STOP Tampering of Products, EU 6th Framework Programme (STREP), http://www.stop-project.eu. Accessed 9 Nov 2012
74. Suchman L (2002) Located accountabilities in technology production. Scand J Inf Syst 14(2):91–105
75. Suchman L (2007) Human-machine reconfigurations: plans and situated actions. Cambridge University Press, New York
76. Weiser M (1991) The computer for the 21st century. Sci Am 256(3):94–104
77. Wright D, Gutwirth S, Friedewald M, Vildjiounaite E, Punie Y (2008) Safeguards in a world of ambient intelligence. Springer, London
78. Woods DD, Dekker SWA (2000) Anticipating the effects of technological change: a new era of dynamics for human factors. Theor Issues Ergon Sci 1(3):272–282