Envisioning Improved Work Practices and Associated Technology Requirements in the Context of the Broader Socio-technical System

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1. Introduction

Work practice and technology innovation presents a number of challenges for Human Computer Interaction (HCI) designers. Chief among them is the question of devising suitable HCI methods, for future process and task envisionment and related technology design. Methods must facilitate work practice re-engineering/envisionment and the development of user friendly work tools. Despite the future oriented nature of this activity, and its associated outputs, research must be predicated on a clear model of existing processes, task practices and tools usage.

HCI research in both commercial and technology research settings, is undertaken in the context of the broader software development process. As such, HCI methods must deliver clear user requirements for use by Software Developers. Nonetheless, HCI resources may be limited, or the research subject to time constraints - impacting on the scope of HCI research. As such, a valid research design which delivers on the core research brief, while taking into account project constraints, is required.

HCI design methodologies are used at different points in the software development lifecycle to design new technologies or re-design existing technologies, in the context of both open and closed systems. Typically, open systems involve the performance of a series of work processes requiring both individual and/or group task activities. Usually, these activities require operator interaction with a range of technical (e.g. IT systems) and human agents. Further, such interactions are subject to external influences. In contrast, closed systems are characterized by one to one user interaction with simple software packages in office or home computing settings. These interactions are unaffected by external influences.

This chapter focuses on the use of HCI methods in the context of open systems (or socio-technical systems). Specifically, it investigates methodologies for the envisionment of new or improved task practices and associated technology requirements, taking into account the broader socio-technical context for human machine interaction. First, an overview of the methodological implications of a range of conceptual frameworks, relevant to an understanding of human interaction with computer systems in socio-technical settings is

provided. Following this, a summary of the software development process and the different requirements distinguished in this process, is presented. An introduction to Human Factors and HCI is then provided. Proposed HCI methodological requirements are then specified. Following this, specific HCI and work analysis methodologies are reviewed, as part of identifying an overall integrated HCI design approach. This is followed by an examination of certain practical challenges facing HCI practioners. In so doing, the author will consider the application of best practices in a real world setting, where HCI research is subject to commercial, technical and organisational constraints.

The HCI methodology outlined in this chapter may be of interest to HCI researchers or practitioners tasked with process and technology envisionment, and/or investigating the links between HCI theory and methods. The specific HCI research methodology proposed and related discussion of practical issues is also relevant to HCI researchers working with limited resources in both commercial software development and/or technology research settings. Further, the specific user requirements gathering methods examined, may be of interest to Software Developers and/or Business Analysts.

2. Conceptual Frameworks and Methodological Implications

2.1 Background

It is well established in the HCI literature that technology systems either fail, or do not perform as well as they might do, because they are not optimised from a user task perspective (Norman, 1988, 1993 and Preece, 2002). Perhaps this seems an obvious point. However, defining the nature of the task, and envisioning new or improved work practices and associated tool requirements, is not a straightforward activity. The question 'what is the task' must be explored on a number of levels. This links to certain theoretical models concerning the relationship between process, task and technology design, and specifically, the relationship between operator task performance and tools and information flow design. Importantly, an investigation of these models suggests certain methodological requirements for HCI design.

2.2 Introduction to Socio-technical Systems

In order to understand the methodological requirements for technology design in socio-technical settings, we must first understand the nature of socio-technical systems and how they perform. A 'socio-technical system' is defined as any instantiation of socio and technical elements engaged in goal directed behaviour. In place of a formal definition, engineering psychologists have proposed a range of characteristics to describe these systems. Characteristics include: large problem spaces, social, heterogeneous perspectives, distributed, dynamic, potentially high hazards, many coupled subsystems, automated, uncertain data, mediated interaction via computers and disturbances (Perrow, 1984, Vicente, 1999).

2.3 Basic Concepts Socio-technical Systems

The definition of a number of basic concepts in socio-technical systems helps illuminate certain aspects of the HCI design problem, which should be considered by HCI

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professionals. Before discussing socio-technical systems theories, a brief explanation of a number of basic socio-technical concepts is provided.

The operational goal refers to the purpose of the operation or the state of affairs to be achieved (e.g. safe and on time flight). This is associated with a series of operational states necessary to the achievement of the goal and a specific 'end state' which marks the successful accomplishment of the operational goal. The operational process defines the logic or structure of work, so that the operational objective is achieved. This includes the distribution of work or task activities between different human and technical agents and the overall timeline for this (e.g. sequencing of tasks). An operational process can be divided into a number of sub processes. Typically, this includes a planning process and the active operation. The active operation requires certain prior work to be accomplished (e.g. all technical and human resources in place). This work is undertaken in the planning phase. In the active operation, the planned work is executed. The operational process can be conceptualized in relation to a series of process gates (or critical points in the operational process). At each process gate, work must be accomplished by different operational agents, so that the process can move forward. Overall, the collective accomplishment of work at each of these process gates, results in the achievement of the operational goal. The process state refers to the status of the process at any point in time, in relation to the achievement of specific operator tasks. A process dependency refers to a relationship between two different parts of a process or two sub-processes. For example, the relationship between the planning sub process and the active operations sub process. Process dependencies also include dependencies between two related but different processes. In terms of a flight operation, this could be the relationship between the active flight operation, and the line maintenance process. Underlying these process dependencies are specific task dependencies. The operational plan describes how the operational goal will be achieved from an organisational perspective. This includes a definition of what human and technical resources will be used at different points in the operation. It also includes any regulatory requirements to be adhered to. Certain background organisational processes are required to ensure that the operational objective is achieved in a safe, efficient and legal manner. This includes the management of a range of organisational functions such as procedures design, documentation management, training, human resources, safety management and risk management.

The realisation of the operational goal requires the accomplishment of work or tasks by different members of the operational team. In socio-technical systems, work is realized by a number of operational agents or resources. This includes human and technical resources. Human resources refer to the people in the system. Technical resources denotes both the tools used by operator to perform their tasks (e.g. procedures, paper tools, IT systems), and all relevant technology (e.g. machines or systems) required to achieve the operational objective. In socio-technical systems, the work environment is distributed in space. As such, both human and technical resources can be situated in similar or remote locations.

Individual units of work are described in terms of tasks. As defined by Kirwan and Ainsworth, a task is 'a set pattern of operations, which alone, or together with other tasks, may be used to achieve the goal' (1992). Task performance is the enactment of the relevant operational task in time and space. The literature distinguishes between the performance of technical and non technical tasks. Technical tasks refer to specific physical tasks undertaken in order to achieve the operational goal. Typically these tasks are described in company

standard operating procedures documentation. Non technical tasks denote the cognitive and social aspects tasks that underlie technical task performance. This includes situation assessment, decision making, task management, communication and co-ordination. Often these are not defined in company documentation. Further, it should be noted that task practice does not necessarily follow the task descriptions provided in company SOP. As such, SOP task descriptions should not be read as definitive.

Depending on the work requirements, operators may perform individual tasks in a sequence, or a number of tasks may be performed in parallel. Typically, tasks are analysed in terms of a hierarchy (e.g. task, sub-task and actions). Depending on the complexity of the task, the task might be grouped into a number of smaller steps or sub-tasks. A sub-task reflects a grouping of related actions, which form an overall step in a task. An action refers to the smallest unit of activity. Actions are associated with human roles, machines/tools and technologies. In relation to human performance, this includes technical activity (e.g. selecting a control on an information display or panel) and non technical activity. Non technical activity includes a range of cognitive (e.g. attending to information on a display, decision making) and social functions (e.g. communicating or co-ordinating with other operators in relation to work activities).

Task dependencies refers to relationships between tasks (both technical and non technical tasks) performed by individual operators or by a group of operators (collaborating on the same task, or producing outputs relevant to each others tasks) at different points in time, throughout the process. Two types of task dependencies can be distinguished. This includes prior or sequential dependencies and parallel dependencies. Prior dependencies refer to task activities and associated task outputs performed by the same or other operators, which are inputs to next phase of work. Critically, there are two aspects to this. Firstly, task performance must be considered in terms of task completion. The task needs to be completed, so that the process can continue. In the example of a flight operation, the Captain must obtain technical signoff of aircraft, before proceeding to close the doors and commencing aircraft push-back. Certain tasks can span a number of process gates or not. However, at a certain point in the operational timeline, tasks become mandatory from a process stability perspective. Also, the quality of task performance must be considered. Tasks may be performed, but the quality of task performance may be weak. For example, poor briefing or situation awareness at one point in flight can have a knock on effect on task performance at a later point in flight. Parallel dependencies concern work undertaken in parallel by other agents, which is an input to the operator's task.

In socio-technical systems, human actors are assigned a role. This corresponds to a set of functions or tasks that they are required to perform in relation to the achievement of the operational goal. Certain actors may have the same overall role, but perform different tasks based on their rank or seniority. Further, in team work situations, a number of actors may collaborate in the performance of the same task or different tasks, either in sequence or in parallel. These actors might have similar roles and ranks, or similar roles and different ranks, or different roles. Consequently, for each task we must distinguish the (1) active role (directly involved in the task) and the (2) supporting roles (contributes or provides inputs but is not directly responsible for the task). The supporting role might include actors with a similar role to the active role, or with different roles. Importantly, the supporting role may or may not be involved in the performance of other tasks at the same time. As such, we must consider how the actions of other agents relate to primary role actions.

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Task performance often requires the use of different types of tools. A number of definitions of tools are provided. Overall, a tool can be defined as a thing (concrete or abstract) that supports task performance - either directly indirectly. From a workplace perspective, the term 'tool' refers to a range of entities - both real and abstract - which are used to perform tasks or to assist in the performance of tasks. This includes paper based information resources (e.g. paper based descriptions of a task or procedure, checklists etc), machines (e.g. mechanical machines, simple computer systems and complex computer systems) and human based information resources (e.g. memory, mental models, expertise, cognitive methodologies and so forth). In this respect, workplace tools can be physical (e.g. paper tools or IT systems) or non physical (e.g. best practice methods or expertise). Critically, workplace tools allow operators to perform tasks that are difficult or impossible given certain physical and/or cognitive limitations. For example, tools can provide a mechanical means to undertake certain physically complex or dangerous tasks. Further, tools enhance our ability to complete difficult cognitive tasks (e.g. processing large amounts of information). In this way tools shape task performance and in particular, extend our cognitive abilities (Norman, 1988, 1993). Certain types of tools are referred to as 'information resources'. An information resource is a tool that provides information relevant to the performance of a task. Information resources include physical resources (e.g. paper tools and IT systems) and human resources (e.g. other operators in the system who provide information to the operator or the operators own memory or expertise). IT systems can provide different levels of information. This ranges from raw data relevant to the performance of a task, to specific decision instruction – depending on the level of automation provided. Depending on the task and tool design, one or more physical tools and/or information resources are used by operators in the performance of task functions. In complex systems (e.g. such as aviation and process control), operators interact with a range of part-task tools, to complete a task. In this instance, the range of part task tools form a system of tools which taken collectively support task performance. From a task performance perspective, integration between different systems or tools is critical (Wickens, 2000).

2.4 Socio-technical Systems Theories & Methodological Implications

What is the nature of socio-technical system performance? How do the elements of a socio-technical system relate? Further, what are the implications of socio-technical system performance theories in terms of HCI research design? A number of theories have been advanced in relation to the overall elements of a socio-technical system. Collectively, these theories build on the basic conception of a socio-technical system as containing three overall elements. This includes the social system, the technical system and the environment. This follows from the socio-technical models of Pasmore (1988) and Trist (1981). Further, it links to frameworks associated with Activity Theory (Leontev, 1974). Overall, socio technical theories emphasize the inter-related nature of the social and technical aspects of a work process. Central to these theories, is the contention that there is a relationship between individual task performance and the design of the overall operational and organisational system (McDonald, 2004, 2006). Specific theories highlight the importance of certain social aspects of organisational performance. This includes the role and organisation of people (e.g. linking to the design of processes and procedures) and the specific social interactions that underlie task performance (e.g. communication and co-ordination). Further, theories point to the gap between formal processes and actual operator task practices. The

implication of these theories is that design methodologies should allow for an understanding of the socio-technical context for task performance. Specifically, proposed technology concepts should be embedded in a broader system model. In particular, future technology envisionment must take into account the relationship between task and process. This includes both operational and organisational processes.

2.5 HCI & Information Behaviour Frameworks & Methodological Implications

A range of theoretical frameworks have been proposed to describe human interaction with computer systems, in the context of socio-technical systems. This includes HCI theories and information flow theories. Critically, these theories can be interpreted as suggesting certain methodological requirements for HCI practioners.

HCI theories such as Distributed Cognition (Hutchins, 1992, 1995, Hollan et al, 2000) and Group Supported Co-operative Work (Bannon, 1991), point to the role of tools and information in shaping operator task performance. Further, such theories emphasize the sense in which operator task performance often involves collaboration with other human and technical agents. The implication of these theories is that proposed methodologies should allow the researcher to understand how tools and information shape task performance. Further, methodologies might facilitate the identification of information flow requirements linked to the task performance of all relevant team agents – both human and technical.

In relation to task performance, HCI theories refer to the task problem to be solved or the task objective. Critically, the tools that operators use provide a means to solve the task problem. In this respect, HCI theorists (Norman, Carroll and Bannon) argue the specific design of a tool influences both the nature of the task and how it is performed (e.g. task workflow and level of complexity). Specifically, Norman (1993) uses the term 'cognitive artefacts' to describe those tools that given their design (e.g. task representational qualities), simplify the nature of the task.

As observed by Carroll (2000, 2001), the introduction of new tools can change the overall nature of the task. Further, it can change the nature of the operational process (Mc Donald, 2004). Carroll's (2000, 2001) concept of the task artefact lifecycle is relevant here. New technology requirements cannot be premised on existing task practices and associated problems alone. Carroll argues that we must envisage improved task practices (or future use scenarios) and consider how technology might support this. That is, we must consider how technology might be used to transform the task. In identifying future technology requirements, the researcher must balance two task pictures. This includes the existing task performance picture and the potential new task performance picture, facilitated by the introduction of new or improved technologies.

The literature highlights the necessity of developing tools from the perspective of the full task and not in isolation. As noted by Wickens (2000), individual displays supporting part task functionality cannot be designed in a vacuum. Rather, the wider tools picture must be evaluated. Here HCI designers must consider issues related to design consistency and information integration across the range of tools used by different operators. This is no easy task, but nonetheless requires consideration.

Information behaviour theories (Wilson, 1999) illuminate a range of operator information management processes in socio-technical contexts. This includes processes related to information gathering, information interpretation, information classification and

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prioritisation, information communication and information use. From a methodological perspective, this suggests that HCI methodologies should allow the research to model human information behaviour and associated information management strategies, so the proposed new technologies are predicated on an appropriate task and information picture, prioritise key user information and facilitate information sharing with all relevant human and technical agents involved in the task activity. Further, it is well documented that the format in which information is presented to the user, impacts on the perception, interpretation and use of this information. Here, we need to consider the HCI aspects of information access and presentation. As such, methods should allow the researcher to properly assess such issues so that user friendly design solutions are advanced.

3. Introduction to Human Factors & Human Computer Interaction

3.1 Human Factors

The Human factors discipline arose in relation to understanding the human role in socio-technical systems. The International Ergonomics Association (IEA) defines Ergonomics (or Human Factors) as

'The scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance' (2000).

The IEA distinguish three domains of specialization within the discipline of ergonomics: Physical ergonomics is concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they relate to physical activity. Cognitive ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. Organizational ergonomics is concerned with the optimization of socio-technical systems, including their organizational structures, policies and processes.

3.2 Human Computer Interaction

Human computer interaction is a multi-disciplinary subject focused on the design of human friendly technology. Different definitions of HCI have been provided. In certain definitions, HCI is regarded as a subset of Human Factors concentrating on the design and evaluation of technologies, while in others it described in similar terms as Human Factors. This is also complicated by the fact that the term HCI is often used interchangeably with 'Engineering Psychology', 'Cognitive Ergonomics' and 'Human Factors'. In this analysis, HCI can be considered as a sub-set of theory and methodologies within HF, concerned with the design and evaluation of technology for use in the context of both open and closed systems. In terms of the three strands of Human Factors defined above, it can be broadly classified as Cognitive Ergonomics.

According to HCI theorists and practioners, to design human friendly technology which fits the work context, we must adopt a 'user centered design' methodology/process. The HCI literature defines a range of methods for this. Collectively, these methods emphasize: (1) the necessity of involving users in design process, (2) the degree to which design is an iterative process (e.g. designs are prototyped and evaluated and the modified and evaluated again), and (3) the extent to which evaluation provides an empirical basis in which to evaluate/justify designs.

4. Software Development Process

HCI methodologies are adopted in the context of developing software/technologies following project goals and timelines. This process is referred to as the software development process. This process follows a number of high level stages including, (1) specifying user requirements, (2) specifying functional requirements, (3) application development, (4) testing, (5) trials and (6) full implementation. Critically, a range of HCI techniques are used for different purposes (e.g. specifying requirements, designing prototypes, evaluating prototypes etc) at various points in this process.

The software development process involves the specification of a number of different types of requirements. This includes user requirements, system/functional requirements, user interface design requirements and usability requirements. User requirements refer to what the system needs to do from the user's perspective (taking into account that there might be a range of different users). System requirements refer to what the system actually does (e.g. list of functions that the system performs and analysis of each function). User interface design requirements refer to what the user interface will look and feel like, and how users will interact with different system functions. Finally usability requirements refer to the acceptable level of user performance and satisfaction with the system. It is important to note that both user requirements and user interface design requirements can be defined at different levels. Depending on the level of specification (e.g. requirements stated in the form of general guidelines or visual prototypes) more or less design instruction is provided to Interface Designers and Software Developers. Evidently, both user requirements and user interface design requirements must be specified at a sufficiently concrete level so that (1) Software Developers can document the functional specification (e.g. functional requirements) linking to application development and (2) Graphic and Interaction Designers can produce the full interaction and visual design model. According to participatory design advocates, one of the weaknesses of formal HCI methods, is that typical outputs (e.g. lists of users and tasks, task analysis diagrams, task scenarios and so forth), fail to provide sufficient design guidance. This is discussed in more detail, later in this chapter.

5. HCI Design Methodological Challenges

So what should HCI design methodologies achieve? How should the range of HCI methodologies serve HCI design practiioners in terms of envisioning new or improved work practices, and associated technologies in socio-technical system settings?

It is argued that HCI design methods should fulfil the following objectives:

1. The development of an appropriate task model

2. Evaluation of existing tools & information resources

3. Envisionment of new tool requirements & associated task practices

4. Understanding broader organisational and technological implications of proposed tool concepts

5. Specification and evaluation of proposed user interface for new or improved tool concepts

6. Facilitation of communication of user requirements and design concepts to Software Developers & Graphic Designers

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5.1 The Development of an Appropriate Task Model

Firstly, HCI design methods should allow for the development of an appropriate task model. This involves a consideration of both existing task practice and future task practice. In relation to the former, methodologies should assist the following:

1. Modelling actual task practice, taking into account different operational and environmental contexts (e.g. ecological validity)
2. Modelling operator task activity and information flow (including collaborative work activity)
3. Modelling the relationship between task and process (e.g. design of both operational process and background organizational processes).
4. Modelling the both technical and non technical aspects of task performance
5. Modelling information flow requirements (e.g. information in an out and how this is facilitated by the use of tools and information resources (both human and technical)

In terms of future task practice, methods should allow the researcher to identify how task practice might be improved given new technology possibilities.

5.2 Evaluation of Existing Tools and Information Resources

Design methods should also allow the researcher to assess the use of existing tools and information resources. For example, task problems associated with existing technology design constraints might be ameliorated by rethinking the current design.

5.3 Envisionment of New Tool Requirements & Associated Task Processes

Proposed HCI design methods should allow for the identification of new tool requirements and associated operational processes based on the task model and evaluation of existing tools. Critically, the resulting tools should represent an improvement on the existing situation. This may involve the envisionment of new operational processes along with new task practices. As such, the design methods should allow for both process and task envisionment. Further, to mitigate problems in relation to the task artefact lifecycle (Carroll, 2000, 2001), such methods might allow the researcher to evaluate the future use situation and associated tool concepts. Importantly, new designs should not inherit the weaknesses of earlier designs, no introduce any new HCI problems.

5.4 Specification and Evaluation of Tool Concepts

Further, design methods should facilitate the prototyping of new tool concepts, thereby bridging the gap between requirements specification and design. Also methods should allow for the evaluation of tool concepts, to ensure that they are optimised in terms of user tasks and conceptual models. Further methods should allow researchers to assess whether human performance and environmental constraints are factored into the proposed HCI design solution.

5.5 Understanding Broader Organisational & Technological Implications of Proposed Tool Concepts & Associated Feasibility Issues

Also, methods should facilitate the assessment of whether or not the proposed technology requirements are achievable. First the researcher must consider feasibility in terms of

existing organisational structures and roles, resource capacity and redesign requirements. To this end, methods should facilitate the identification of the task/performance requirements embedded in the proposed technology design, and whether this requires changes to existing work practices and/or resource allocations. There may be organisational barriers to changing existing work practices. For example, new tool concepts may require communication or sharing of information between different roles or departments. Certain departments may not want to share information. Further, there may be data protection issues linked to Union agreements or regulatory rules, which prohibit data sharing. In addition, new tool functionality (e.g. the provision of task support information customised to an operation) may require additional work effort/human resources. Does the organisation have the capacity for this? Can new functions be incorporated in existing roles, or are new employees required? What are the training implications?

The design of technology for use by individual groups of operators in socio-technical contexts often links to the design of technologies used by other roles in the organisation. In particular, the provision of information to specific end users, related to collaborative work activities necessitates information sharing across the different human and technical agents involved in the work activity. As such, methodologies should assist researchers in identifying the relevant information integration requirements inherent in the proposed technology concepts. Further, proposed methods should permit the identification of any additional technology requirements linked to the task performance of other operational roles, which may or may not be supported by existing tools.

5.6 Facilitate Communication of User Requirements and Design Concepts to Software Developers & Graphic Designers

Lastly, it is critical that the analysis and design outputs of the HCI design methodologies adopted, can be utilized by Software Developers, in terms of specifying the functional requirements of the system. Moreover, the outputs need to be instructive in terms of specifying the user interface design requirements for the proposed system, which is managed by the Graphic Design team.

6. Overview of HCI Methods

Do HCI methodologies facilitate the above objectives? Or, are other methods required? The literature distinguishes two high level sets of methods, namely formal and informal HCI methods. In general, formal methods are characterized as being closer to scientific methods. Alternatively, informal methods are strongly linked to design activities and considered to have a more qualitative focus

6.1 Formal HCI Methods

Formal methods in HCI allow for user involvement at specific points in the software development lifecycle (Nielsen, 1993, Constantine et al, 1999, Mayhew, 1999).

First, a task analysis is conducted, to understand how the operator interacts with the existing system and to identify the user requirements for an improved or new system. According to Kirwan and Ainsworth (1992), a task analysis *is a method of describing what an operator is required to do, in terms of actions or cognitive processes, to achieve a system goal*. Usually, this occurs at the beginning of a project and takes the form of structured or semi-

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structured interviews focused on understanding and evaluating current work practices and supporting technology (Hackos et al, 1998). This follows ethnographic research methods, advanced in the Social Science field (e.g. Interviews and Observation).

A number of analysis and design steps are then completed by HCI professionals without the participation of end users. These techniques aim to represent the cognition, practice or logic of the task. In addition, they aim to identify user requirements. Typical analysis methods include content analysis, hierarchical task analysis and task workflow analysis.

Design concepts are then modelled with the help of Graphic Designers. This involves mapping user tasks and workflows to a set of interface screens with a defined information structure and presentation logic. Initially, HCI designers might map a high level storyboard. Following this, a more detailed storyboard is modelled. Detailed storyboards include rough sketches of screen layouts and designs that correspond to the use sequence outlined for a detailed level of a task performance by a system. This process is supported by a wealth of advisory information relating to user interface design. This includes International Organisation for Standardisation (ISO) user interface design approaches and standards (ISO, 1995, 1997), and usability design principles/heuristics (Nielsen, 1993, Preece et al, 2002).

Following this, prototypes are modelled. Developing prototypes is a central part of user centred design. A prototype is an experimental or incomplete design. This links to the distinction between specification and implementation. A prototype belongs to specification/design phase, as opposed to the implementation phase. Different kinds of prototyping are appropriate for different stages of design. Once the prototypes are completed, user workflows and interface features/behaviours are evaluated. In HCI design, evaluation is part of the design process. Evaluation is part of the design process. Feedback is obtained about the usability of designs via inspection, testing or enquiry. This is an iterative process. Evaluation occurs at different points in the development process. The goals of evaluation are multiple and varied. Evaluation can be used to investigate what users want, if user requirements are being met and what problems users have. Further, it can be used to test out design ideas/concepts quickly and to assess the usability of a UI and improve the quality of the UI. Two main evaluation methods are used. This includes (1) user testing and (2) heuristic evaluation. User testing involves the assessment of a user interface (UI) by observing representative users performing representative tasks using the UI (Rubin, 1994). This is used to identify any aspects of a design that cause users difficulty, confusion, or misunderstandings. These may lead to errors, delays, or in extreme cases inability to complete the tasks for which the UI is designed. User testing also provides insight into user preferences. In addition, a heuristic evaluation may be conducted. In a Heuristic Evaluation, the UI is examined against a set of agreed usability /user experience principles (the heuristics). This is undertaken by a team of experienced usability professionals (the evaluators). As such, the evaluation does not involve end users. The evaluator or team of evaluators step into the shoes of the prospective end user – taking into account their profile, mental models of the task, typical learning styles and task requirements. Following iterative prototyping and evaluation, high fidelity prototypes are developed by software developers.

6.2 Informal HCI Methods

Formal HCI methods have been the subject of much debate in the HCI literature. Specific challenges have come from the fields of Ethnography and Participatory Design.

Ethnographers argue that classical HCI methods do not take work practice seriously; failing to address the social aspects of work (Hutchins 1995, Vicente 1999). In particular, they argue that user interviews cannot provide actual insight into real work practices. Participatory design theorists have questioned the separation between design and evaluation in formal methods (Bødker and Buur, 2002). Specifically, they have challenged the instructiveness of traditional user and task analysis outputs for design guidance. Also, they argue that user testing provides insufficient information concerning user problems. Further, PD theorists have questioned the usefulness of these methods for the design of both socio-technical systems and ubiquitous technology (Bodker and Buur, 2002).

The field of participatory design originated in Scandinavia in the early 1970s, in response to union mandates that workers should be involved in the design of new workplace technology. This heralded the introduction of new HCI methodologies, many of which were pioneered in the Utopia Project (Bødker, 1985). Central to PD theory is the idea that usability engineers design 'with' end users, as opposed to 'for' them. Accordingly, users are active participants in the design process, and the traditional HCI design team (e.g. Usability Engineers and Graphic Designers) is broadened to include end users (workers and worker organizations), stakeholders and domain experts. Crucially, PD theory stresses the relationship between design and evaluation. PD theorists argue that to design effective work tools, design teams must first experience and evaluate future technology and practices (Bannon, 1991, Muller 2003). As such, PD techniques (such as, the co-creation and evaluation of prototypes and scenario role playing), allow design teams to envision and evaluate future workplace practices and related technologies, without the constraints of current practice. Overall PD techniques have been adapted from Ethnography. This includes concept generation, envisionment exercises, story collecting and story telling (through text, photography and drama), games of analysis and design and the co-creation of descriptive and functional prototypes.

The PD contention that users must be active participants in the design process, (and related argument that Usability Engineers should be receptive to user's own ideas and explanatory frameworks) reflects certain underlying phenomenological conceptions of knowledge. Participants are not objects but partners or 'experts' whose ideas are sought. Thus, it is inappropriate for human factors researchers to formulate design models in advance of collaboration with end users. In this respect, PD theorists argue that there are four dimensions along which participation could be measured. This includes: (1) the directness of interaction with the designers, (2) the length of involvement in the design process, (3) the scope of participation in the overall system being designed and (4) the degree of control over design decisions.

Critical to PD methodology is the envisionment of future work situations. According to PD theorists, users need to have the experience of being in the future use situation, or an approximation of it, in order to be able to comment on the advantages and disadvantages of the proposed system. As argued by Bannon, some form of mock-up or prototype needs to be built in order to let users know what the future use situation might be (1991). This allows users to experience how emerging designs may affect work practice.

Carroll proposes a scenario based design approach (2000, 2001). This links to the development of persona's and task scenarios, used in formal HCI approaches. This approach distinguishes the development of existing task scenarios (describing current practice), and future task scenarios (or future use scenarios). According to Carroll, future

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use scenarios are narrative descriptions of a future task state. This relates to the participatory design techniques of imagining future work processes and supporting technology (described above). Further, it relates to Carroll's concept of the task artefact lifecycle. For Carroll, the task artefact cycle is the background pattern in technology development (2000, 2001). Possible courses of design and development must be envisioned and evaluated in terms of their impacts on human activity (before they are pursued). If – If Designers model technology in terms of the existing task practice (e.g. model what is), the technology will be one step behind (Carroll, 2000, 2001).

Further, the application of participant observation methods developed in the Social Science field, have also been proposed. The purpose here is to obtain a picture of real world task practices and associated environmental constraints. This is based on the idea that participant feedback in interviews (used in formal methods) may not provide a true or accurate picture of the actual work reality. These methods have been supported by Hutchins. According to Hutchins, it is through Ethnography that we gain knowledge about how a distributed system actually works (1995).

7. Overview of Methods Used in Organisational Ergonomics Fields

HCI methods are influenced and/or have much in common with specific work analysis methods used in the organisational ergonomics domain. This includes Process Mapping and Cognitive Work Analysis.

7.1 Process Mapping

The objective of process mapping is to model the current process and identify process re-design requirements for the purpose of improving safety, or productivity. This relates to business process modelling (e.g. modelling 'as is' and 'future processes'), with the objective of improving efficiency and quality. Process mapping involves the production of a diagrammatic representation of the overall process, and associated sub-processes. Specifically it represents the sequential and parallel task activities of both human and technical agents, which collectively result in the achievement of the operational goal. This approach originates in the research of Gilbreth and Gilbreth (1921). Underlying this visual map is an analysis of the process as a functional system (e.g. transformation of inputs into outputs, process dependencies), as a social system (e.g. team performance requirements, co-ordination and communication mechanisms) and as an information system (e.g. transformation of information across different technical and human resources). Typically process mapping is conducted in a workshop format involving all relevant stakeholders involved in the operational process. First, the researcher reviews the high level process and then drills down to chart the related task activities of different roles. As part of this, there is usually some form of trouble-shooting related to identifying existing process problems and redesign solutions.

7.2 Cognitive Work Analysis

Vicente argues that in dynamic work settings, there are many factors outside the individual affecting their interactions with computer systems and these factors must be considered in the design of such systems (1999). In this regard, Vicente contends that to understand work demands both cognitive and environmental constraints must be considered. Vicente

methodology is based on Rasmussen's argument that the work environment determines to a large extent the operator constraints and the ability of the operator to choose his/her own strategy. In Vicente's view, environmental constraints come first (Vicente, 1999). To this end, Vicente (1999) proposes a cognitive work analysis (CWA) methodology to analyse work. This includes both task and work domain analysis. CWA consists of five concepts and corresponding analysis. This includes, (1) an analysis of the boundaries and restrictions of the work domain, (2) an analysis of the information processing parts of the task, (3) an analysis of the process and associated task performance, (4) an analysis of social organisational and co-ordination and (5), an analysis of worker competencies. This methodology has been applied to diverse work situations involving varying degrees of process control/automation.

8. Analysis

Operator work in socio-technical contexts can be quite complex. Often it involves the performance of collaborative activities with a range of human and technical agents. As such, task activity and human computer interaction in open systems is more demanding than in closed systems. It is argued that (1) the modelling of task activity and (2) the envisionment, design and evaluation of improved task support tools in socio-technical contexts, necessitates the application of a range of design methods, above and beyond what is outlined in the HCI literature (e.g. both formal and informal HCI methods). Taking into account the methodological requirements outlined earlier, it is suggested that HCI researchers adopt a mix of methodologies associated with two of the three Human Factors fields, namely Cognitive Ergonomics and Organisational Ergonomics. Specifically, an integration of formal HCI methods, informal HCI methods and both process mapping and cognitive work analysis methods is proposed. Typically, HCI practioners working in socio-technical settings use a range of both formal and informal HCI methods. Further, certain work analysis techniques such as Cognitive Work Analysis have been applied by HCI practioners. Other methods such as process mapping methods have not been used.

Existing HCI methods do not support an analysis of the relationship between task, process and technology requirements. Specifically, to design 'operational' technologies, HCI researchers must understand how existing and future technologies relate to the design of the existing process and/or future process. The introduction of new technologies has implications for broader task practice (e.g. task practice of other agents) and the design of the operational process. As such, we cannot just think of technology from the perspective of the task performance of one role, or in isolation from the broader process design. To this end, in analysing task performance, we must distinguish two perspectives on task activity – (1) the specific user perspective and (2) the broader system perspective (e.g. takes into account the broader operational and organisational aspects of task performance). Insofar as both perspectives relate, this is not a real distinction. However, this distinction is useful from an analytic perspective. The individual perspective focuses on task performance in terms of unique roles. Here we consider the overall task picture, how tasks relate, actual task workflows (e.g. difference between SOP and actual practice), task information requirements, use of tools and environmental constraints. Critically, this perspective prioritises the task requirements of the individual operator. The system perspective investigates task performance on two other levels – the operational level and the

organisational level. The operational level takes into account collaboration with other roles and associated task information inputs and outputs. As such, it reflects a process perspective on task activity – factoring team collaboration requirements into task models. This links to the computer supported cooperative work frameworks proposed by Bannon (1991) and others. The organisational level examines task performance in terms of those processes in the organisation that support task performance. For example, training, safety management and procedures design. Process mapping workshops can be used to model the existing operational process and envisage future processes and associated re-design requirements. Also, interviews and observations can be used to map relevant work processes.

Formal HCI design methods do not support the envisionment of future work practices and associated technology requirements. To this end, informal HCI methods are required. It is argued that participatory design methods facilitate technology envisionment and provide concrete design instruction. Collaborative prototyping of proposed tool concepts with end users allows both the researcher and participants to envision future use scenarios and associated technology requirements. Further, these techniques enable practioners to elicit feedback relating to the usability of future technology concepts - thereby circumventing the task artefact lifecycle. Crucially, the application of these methods results in the advancement of meaningful requirements. User requirements and associated interface concepts are translated into actual user interface features and behaviours. Prototypes can be used as a basis for exploring, evaluating and communicating design ideas. Indeed, it is difficult for participants to fully envisage and evaluate design ideas, without such prototypes. Essentially, techniques allow both users and designers to experiment with different visual/interactive affordances (e.g. menu structures, icons, presentation of form fields) until a design consensus is reached. Further, certain visual and interaction issues require 'hands-on' problem solving. In this way, research does not stop short of concrete solutions. However, as a stand-alone methodology, participatory research methods are insufficient. To design tools that improve upon current practice, we must start from current practice. To interpret and weight participant opinions related to specific design solutions, the researcher must be familiar with the existing problem space. As such, naturalistic research methods (e.g. interviews and observations) are a necessary precursor to PD methods.

Both HCI methods and organisational analysis methods do not facilitate the identification of the broader organisational and technological implications of new tool concepts. It is suggested that process workshop methods are adapted to this purpose. The specific methodology for this is outlined in subsequent sections.

9. Proposed Methodological Approach & Case Study Examples

The proposed integrated HCI design methodology can be grouped into a series of design steps at different points in the user centred design process. The specific steps proposed relate to HCI research only. Some of these steps are required, while others are optional. Further, certain steps depend on the project context. It is recommended that practioners adopt this methodology for their own purpose, taking into account relevant project considerations. Other work, relevant to the performance requirements of the wider software development team is alluded to in terms of dependencies with HCI work, but not described in terms of actual steps. This includes the production of the graphic design, the specification

of functional requirements, software development, software testing, software and hardware integration and testing, trial implementation of proposed systems and full implementation of proposed systems.

Step	Description	Required, Context Dependent Or Optional	Methods	Output
1	Literature Review	Optional	Review literature available – comparative tools, known problems	Report
2	Identifying the process context underlying operator task performance	Required	Process mapping workshops (existing process) Follow up observation of work practice, or interviews with different stakeholders	Process map of existing process Process analysis templates Role/task descriptions
3	Modelling existing task practice and tool usage	Required	Observation of work practice Interviews with different operational roles User testing User and task analysis	User/task matrices Task scenarios Procedural workflow diagrams User testing report
4	Specification of preliminary user requirements	Depends on project context	Advancement of future use scenarios and associated technology brief Analysis and documentation of requirements	Future use scenarios Preliminary user requirements specification Prototypes (optional)
Management review and decisions				
5	Envisioning new work practices and associated user requirements for new or improved technologies	Required	Process workshops (future process) Technology envisionment exercises Role play Collaborative prototyping	Future / To be process map Future use scenarios High level tool concepts High level paper or MS Visio prototypes
6	Prototyping and evaluating of proposed tool concepts	Required	Mix of individual and collaborative prototyping User testing	Prototypes (MS Visio Prototypes)
7	Dry run implementation of proposed tool concepts to assess organisational and technological implications	Required	Review of proposed scenarios and prototypes, as part of an implementation workshop	Prototypes Implementation Report

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Management review and decisions				
Step	**Description**	**Required, Context Dependent Or Optional**	**Methods**	**Output**
8	Further prototyping and evaluation	Depends on previous – scope of changes	Further prototyping and evaluation (if required)	Prototypes
9	Overall Research Analysis, Further Prototyping & Specification of User Requirements and User Interface Design	Required	Analysis and weighting of all feedback Further prototyping Specification of user requirements	User requirement specification User interface design specification Prototypes Updated process map
10	Handover to Software Developers & Graphic Designers	Required	In person review session – review proposed tool prototypes and relevant documentation	User requirement specification Prototypes
Production of graphic design				
Definition of functional specification				
Initial software development				
Handover of graphic design to software developers				
Further software development				
11	Review Software Prototypes	Required	In person review session (ongoing)	Updated software prototypes
12	Evaluation of High Fidelity Prototypes	Optional	User testing Heuristic Evaluation	Updated software prototypes
13	Tool Certification (ongoing once tool concepts defined)	Depends on project context	Review of regulatory guidance Evaluation with authorities	Certification report
Software testing				
Integration with other software systems and hardware				
Integration Testing				
Trial implementation of new systems in organisation				
Full implementation of new systems in organisation				
14	Ongoing feedback and improvements (after go live)	Optional	Observation of work practice using new tools Interviews with different operational roles Surveys	Implementation report

Table 1. Summary of Proposed HCI Methodology & Associated Steps, Methods and Outputs

Such method triangulation has been used in two different studies conducted by the author. Each of these studies has involved the application of some or most of the design steps outlined above. It should be noted that one of these studies is complete while the other is ongoing. Before presenting the proposed the design steps for the integrated HCI design

methodology, I will first provide a high level background to these studies. Design steps will then be discussed in the context of the HCI methodologies used in these projects.

The first study involved the re-design of an electronic flight bag application as part of a commercial software project (Cahill and McDonald, 2006). HCI resources for this project were limited, thus limiting the scope and depth of HCI research.

The second study concerns the development of improved Flight Crew task support tools, linking to the advancement of improved processes and technologies supporting airline performance management, safety/risk management and continuous improvement activities (Cahill and McDonald, 2006, Cahill et al, 2007, Cahill and Losa, 2007). This project started in 2005 and is due to be completed in 2009. A core requirement for the research was to map the existing process and envision future work processes. As such, process mapping was built into the overall HCI research design.

9.1 Step 1: Literature Review

Before embarking on HCI research, it is necessary to familiarize oneself with the proposed research domain. As such, the first step involves conducting a literature review, specifically investigating what is reported in relation to existing process and task descriptions, existing technologies and future technology concepts. Project sponsors may have certain preconceptions about future technology objectives and requirements. In this respect, the researcher should assess the feasibility of the initial technology development proposal. It is important that a neutral perspective on any of the concepts reported (e.g. both the literature and company requirements) is adopted, so as to avoid prejudicing the research.

In relation to the second study, the literature review highlighted a number of task performance concepts linked to certain theoretical models of Flight Crew task performance (e.g. situation assessment, information management and task management) and related training concepts (e.g. crew resource management and threat and error management), requiring validation in field research. Interestingly, the initial evaluation of these concepts proved critical in terms of the directing future field research, and generating tool requirements (Cahill and Losa, 2007).

9.2 Step 2: Identify the Process Context

The second step involves identifying the process context underlying task performance. The objective is to map the existing operational process, and in particular, to identify the relationship between the task performances of the operator under study, with the task performance of other operational agents involved in the work process and associated information inputs and outputs. This necessitates conducting process mapping workshops with all relevant stakeholders. Depending on time constraints, workshop information can be substantiated by follow up observations of the work activities or de-brief interviews with different operators.

In the case of the second study, the high level process and associated sub-processes were first mapped. Following this, detailed aspects of each sub process were mapped. This included the process gates, process states, the specific tasks and collaboration required by different agents to achieve the process state and relevant dependencies (both at a task and process level). In terms of tools, process mapping can be undertaken using a marker and whiteboard, or using specific process mapping software. In this instance an 'off the shelf' process mapping product was used. Given the notational and visual display logic inherent

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in this tool, not all of the information captured was amenable to representation in a visual display. This information was recorded and linked to the visual map display. Specifically, the process map was supplanted with process analysis templates defining process pre-requisites, operator roles, task dependencies and relationships and so forth. Further, role task descriptions and associated performance requirements were documented.

9.3 Step 3: Modeling Existing Task Practice & Tool Usage

The next step involves modelling actual task practice, taking into account the wider socio-technical process. Ideally, this follows from process mapping activities. As such, the researcher is driving down on the high level process picture to understand in more detail the task activity of the operator for whom the future technology is intended. As part of this, specific task workflows, the use of existing tools and information resources, and overall collaboration and information flow with the different human and technical agents involved in task activity should be analysed. If formal process mapping has not been undertaken, the researcher should endeavour to establish the relationship between task and process and associated dependencies, as part of the task analysis methodology.

Typically, the first point of analysis is company documentation such as standard operating procedures. Usually this documentation does not refer to the social or cognitive aspects of a work process, and the performance requirements of other agents, which link to operator task activity. In relation to modelling existing task practices, it is critical that this reflects what operators actually do as opposed to normative descriptions of task practice (e.g. airline SOP). As noted in the literature, there is often a gap between operator descriptions of work activity (relayed in user interviews), and actual task practice. This necessitates the application of a range of naturalistic research method such as user interviews and observations of work practice. Interviews may be conducted with the primary users. It is useful to create interview templates which guide the researcher through a series of questions, linking task and process and eliciting information about tools and information flow. Further, questions should be asked in relation to the cognitive and social aspects of task performance. Specifically, information management behaviour and communication and co-ordination tasks should be addressed. This links to Vicente's Cognitive Work Analysis approach (1999). In the second study, two phases of interviews were undertaken. The first set of interviews focussed on modelling task workflows and task relationships. The second set of interviews investigated issues related to tools usage, information management behaviour and associated strategies and workflows and techniques related to certain non technical tasks (e.g. situation assessment and joint decision making).

To lend ecological validity to work descriptions, interview data should be co-related with data gathered during observations of actual work practice. Critically, observation of task practice must include both the operators under study (e.g. for whom the proposed new technology is designed for) and any other operators with whom they collaborate. Information gathered can be co-related with interview feedback and analysis templates updated. Further, additional interviews may be conducted to clarify research findings.

In relation to understand the tools and information picture, the researcher might engage in a walk-through of existing tools with research participants. This will help the researcher to understand the strengths and weaknesses of existing technologies and future tool requirements. Alternatively, user testing of existing tools might be undertaken. User testing

of existing tools was conducted in the first study. In the second study, a walk-through of existing tools was performed.

The output of this research can include the following: user/task matrices, existing task scenarios, task analysis templates, procedural workflow diagrams and diagrams of the workspace.

9.4 Step 4: Specification of Preliminary User Requirements

In commercial situations, a preliminary specification of proposed tool objectives and functions and associated user requirements, may be required. Typical reasons include the necessity to report to management, or to furnish Software Developers with draft high level requirements, so that software development activities can be initiated. This is often required in situations where the HCI budget and/or timeline is limited, and HCI research and software development must be undertaken in parallel.

The fourth step therefore involves conducting an overall analysis of the aggregated findings of all preceding research, to envision preliminary future use scenarios, tool objectives and functions and high level user requirements. It should be noted that this step is conducted without the involvement of end users. This can result in a range of outputs – depending on the specific analysis undertaken. This includes future task scenarios and a preliminary user requirements specification. Further, it is possible to produce a draft high level prototype based on this first phase of research. Both future use scenarios and prototypes can be used to help direct envisionment exercises and collaborative prototyping activities at a later point. It should be noted that both future use scenarios and associated prototypes are advanced to illustrate the research findings. These are by no means final. Much can change following subsequent envisionment and collaborative prototyping research with end users. In the case of both study one and two, such an approach was undertaken.

9.5 Step 5: Envisioning Future Work Practices and Associated User Requirements for New or Improved Technologies

The fifth step involves the envisionment of future work practices and the associated requirements for new or improved technologies. The objective is to identify the future work process and associated task scenarios for all relevant agents, and following from this, to scope the requirements for new or improved task support tools. This entails the application of one or a number of the following techniques - future use process workshops, future use scenarios definition and role play, and collaborative prototyping with end users. Typically the application of these methods requires a mix of individual and group participatory sessions.

Future process mapping can be undertaken following the mapping of the existing process or in a separate workshop session. Process mapping of the existing process will have identified a range of process barriers and facilitators. Barriers might include human factors problems (e.g. communication and co-ordination with other human agents) or HCI problems with existing technology (e.g. information not provided, complex or unintuitive interaction or visual design). Problems identified can be recorded on post-it notes and pinned to the walls, for the purpose of group review and joint problem solving. During the workshop participants review all issues, prioritise key problems and engage in joint problem solving. This problem solving is directing at identifying an improved process, new task workflows

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and associated technology tool requirements. Both short and long terms re-design recommendations can be identified.

A number of future use scenario based design approaches can be undertaken. Prior to the session, the researcher may have documented a future use scenario based on earlier research (e.g. process and task analysis). In the session, participants are invited to review the scenario, for the purpose of generating a discussion around future use situations and associated tool requirements. As part of this, both participants and researchers can engage in role play activities, to further clarify the future use scenario and technology implications. Alternatively, the researcher might invite participants to identify their own future use scenario. As before, participants role play specific task activities, detailing what information they would expect to obtain, how they would obtain this information, and how they would use this information. In so doing, the researcher can commence collaborative modelling of high level prototypes with participants. This entails evaluating and further scoping prototypes produced in the earlier analysis (if produced). Conversely, participants are invited to draw out their concepts on paper, with the assistance of the researcher.

Finally, collaborative prototyping techniques can be used (Muller, 1991). Again, depending on the nature of the preceding analysis, this may involve joint envisionment of high level prototypes, or the review and scoping of preliminary prototypes created by the researcher. A series of prototyping sessions is conducted. This starts with the production of paper prototypes. As the research progresses, the researcher can model prototypes using a prototyping tool such as Microsoft Visio. Following this, the researcher updates the prototypes based on an analysis of aggregated findings. Prototypes can be advanced by means of either individual or group session. However, it is important to validate prototypes in group sessions at the end, to ensure an overall design consensus is obtained.

Depending on the approach taken, the outputs of this analysis include the following: future or 'to be' process maps, future use scenarios, high level tool concepts and high level paper or MS Vision prototypes.

In the first study, a range of participatory techniques were used to problem solve usability issues which arose in prior user testing and ethnographic research, and to provide a concrete interaction design model for the proposed new EFB tool (Cahill and Mc Donald, 2006). Specific PD activities involved a combination of requirements' envisionment and the co-creation and evaluation of prototypes. First, a task was described and users were requested to outline the workflow and information requirements (including workarounds and bottlenecks and so forth). For example, participants were asked "If you noticed a new defect on landing, what would you do? What usually happens?" Participants were also encouraged to verbalize workflows, and sketch task-flows, using pencil and paper. As part of this, participants were invited to consider group/collaborative work requirements. Further, participants were shown task workflow drawings (specific user and task analysis outputs) and asked to edit them, where appropriate. This led participants to scrutinize both their own conceptions of workflows, and that of others. This is close to Carroll's (2000) investigation of task scenarios via claims analysis. This resulted in a clear task picture (e.g. task hierarchies, sequences and relationships).

In the second study, the research design involved an integration of technology envisionment and collaborative prototyping approaches, outlined by Muller (1991) and Bodker (1985), with the future use scenario based design approach proposed by Carroll (2000, 20001). Four phases of research were undertaken. First, all prior research was analyzed. This resulted in

the production of high level 'future use scenarios' and associated tool concepts. Following this, initial high level prototypes were advanced for the emerging tool concepts. These indicated the high level workflows and information flow for these applications. The third phase involved the co-evaluation and development of low fidelity prototypes using an off the shelf prototyping tool – namely Microsoft Visio. This required iterative modelling of tool concepts with twelve participants over four days. The overall user interaction design model for each of the prototypes was first reviewed (e.g. navigation and information classification and structure) and feedback elicited. Following this, the high level screens for each of the application concepts were reviewed. Prototype screens were used as a talking point from which to establish more detailed requirements concerning task workflows, information requirements and information structure and presentation. The final phase involved further prototyping and modification of tool concepts following the analysis of all prior research.

9.6 Step 6: Prototyping & Evaluation of Tool Concepts

The sixth step involves further scoping and evaluation of the initial system prototypes advanced in last phase of research, with end users. The objective here is to bridge the gap between high level tool concepts and associated user requirements, and the specification of user interface functions and behaviours. To this end, prototypes are co-developed with end users following the collaborative prototyping techniques outlined earlier. This can involve a mix of collaborative prototyping sessions with individual end users, and/or group sessions. This is an iterative activity and involves a number of prototyping sessions and updates. Following each series of sessions, the research will engage in additional prototyping based on a review of aggregated findings. As part of this, the researcher must consider relevant design guidelines. In the case of the first study, the researcher followed regulatory guidance in relation to EFB human factors. Further, additional written documentation may be provided to outline proposed user workflows and provide an explanation of any user interface objects. For example, the full contents of drop down menus/combo boxes should be specified. Further, user testing of prototypes can also be undertaken. The output of this activity is usually low or mid fidelity tool prototypes.

In the first study, three phases of prototyping and evaluation were undertaken involving four participants per phase. Participants included Flight Crew, Maintenance Engineers, Training Personnel and Domain Experts. Individual sessions were conducted with all participants. Informal group sessions were conducted with project stakeholders/ management, after each PD phase to relay project progress and elicit feedback on specific design decisions. Further, as participatory design work progressed, design feedback was relayed to software developers. After phase two, a provisional model (EFB visual/interaction prototype) was provided to the software development team. Specific task interactions were translated into formal use cases and UML models, by development teams. Later, user interface design and HCI rules (series of behaviours for different widgets and screen elements) were drafted. Both the design model and HCI rules were updated, as research progressed. This often necessitated software edits. This wasn't ideal from a software development perspective (e.g. time and costs rewriting code), but was unavoidable given project requirements (e.g. software development and HCI research to progress in parallel with on-going HCI feedback and updates).

The first phase involved the collaborative design and evaluation, of basic paper prototypes drawing from Muller's PICTIVE technique (1991, 1993). In Muller's technique, users actively

participate in the design of the user interface. Typically, users mock up a design (either individually or collectively) using basic materials (e.g. pencil, markers and paper), with the assistance of Designers and/or Developers. The mock up/prototype is modified repeatedly (users evaluate the mock up and problem solve changes) for a specific time period. Often, the session is videoed to record the specific design iterations and the rationale behind proposed changes. Underlying this technique is the idea that users must experience the proposed technology solution (e.g. either by prototyping the solution or interacting with the solution), to properly critique the emerging work practice and supporting technology solution. In this context, individual participants were invited to draw concepts for specific screens/workflows. Videotaping was not used. Some participants had difficulties visualizing basic screen structures. In these instances, drawings were produced collaboratively. After a number of participant sessions, generic drawings emerged (e.g. integration of results across a number of sessions). In later sessions, participants were asked to compare their drawings with the evolving concept. Again, this encouraged participants to explore complementary workflow concepts and related visualizations. Following on from this some Visio prototypes for specific task scenarios were developed based on the emerging EFB concept. A second phase involved detailed evaluation of these prototypes. First, participants were asked to appraise a simulation of certain interaction concepts explored in Phase One. After this, participants evaluated specific screens/workflows. All participants evaluated the same prototype. Where problems arose, 'on the fly' design changes were made to clarify solutions. Individual problems and recommendations were recorded for each evaluation, and analyzed. A further Visio prototype was designed, based on the findings of prior co-evaluations. The final phase, involved further collaborative evaluations of the Visio prototype. Individual evaluations were conducted and problems and solutions recorded. The output of this phase was a tentative model for the redesigned EFB solution.

In the second study, a series of individual and group participatory prototyping sessions were conducted with end users. Feedback was provided to Software Developers at different points during this activity. First, a series of collaborative prototyping and evaluation sessions were conducted over a two day period. On the first day, collaborative prototyping and evaluation of tool prototypes with conducted with twelve participants. The sessions focussed on evaluating and extending the initial prototypes which emerged in the earlier envisionment activities. Following the analysis of feedback from all sessions, the prototypes were updated. On the second day, the revised prototypes were reviewed with One Pilot. Further, additional user interface screens were scoped. This was followed by a presentation of proposed concepts to a broader airline group. Feedback from this presentation was factored into further prototyping activities by the researcher. Further prototyping and evaluation of proposed tool concepts was then undertaken with one Pilot, over the course of two additional individual sessions. As part of this, the researcher reviewed issues relating to the broader operational and organizational processes underlying the proposed tool concept. This included scoping of existing company tools and links to other tools advanced in the project. This was followed by further prototyping on the part of the researcher.

9.7 Step 7: Implementation & Evaluation of Proposed Tool Concepts in Organization

The preceding research will have generated new work practice concepts and associated user requirements for new or improved tools. The introduction of new work processes may not be possible. Further, the development costs in relation to the introduction of certain tool

functions for primary end users, or the extension of existing tools used by other operational agents to support the work of these primary end users (e.g. supporting information sharing), may be too high. Trade offs may be required. The seventh step therefore involves reviewing and evaluating proposed work practice scenarios and associated tool concepts with different organisational stakeholders, to assess the overall feasibility of proposed tool concepts from an organisational, technical level and commercial perspective. The objective is to assess the feasibility of the proposed technology concepts, and obtain a consensus as to what functions to retain and what to omit. In this regard, technology development might be split over a number of phases. As such, both short term and long term technology development priorities are agreed.

Typically this takes the form of a group workshop with all relevant stakeholders. First the researcher presents the proposed new work practice task scenarios taking into account the task requirement of all relevant roles. Following this, the proposed user interaction with specific new or improved technology tools is described. This can be accompanied by a review of the proposed HCI model for the new or improved system, specific user interface workflows for important tasks and any relevant background documentation. As part of this, the researcher elicits feedback from the group in relation to the proposed work practices for the different agents involved in the work process, and related tool concepts. Problems can be identified and solutions suggested. There may be different views as to the suitability of the new work practices and tool concepts. Feedback may reflect the biases of different roles. In addition, the prototypes may raise certain complex technical issues. This may require a more detailed review. Moreover, proposed organisational changes may be perceived as controversial by certain personnel. As such, a number of workshop sessions may be required. Further, it may be useful to pursue certain discussions on an individual basis. In such cases, the researcher can handover proposed user scenarios, tool prototypes and supporting documentation to the relevant project contact or advocate in the organisation. This person can elicit further feedback from relevant partiers. This feedback can be relayed to the researcher at a later point. Alternatively, the researcher can follow up with specific individuals. This step was undertaken as described above, in relation to the second project only.

9.8 Step 8: Analysis of Feedback & Further Prototyping

The eight step involves the analysis of implementation workshop feedback and further prototyping. Further, the researcher may engage in further review and evaluation of prototypes with end users, if so required. This can become an unending activity. Knowing when to stop is important! The review and evaluation of prototypes typically ends once the researcher is satisfied that the proposed solution meets the agreed requirements and that relevant problems have been surmounted. However, there may not be time (e.g. budget/resources) for exhaustive prototyping and evaluation, and the scope of this evaluation may be curtailed.

9.9 Step 9: Overall Research Analysis, Further Prototyping & Specification of User Requirements & User Interface Design

Step nine entails the analysis of all prior research, for the purposes of specifying the user requirements and user interface design features of the proposed new tool. This necessitates ensuring that all prototypes and associated documentation is in order, to facilitate the

communication and handover of requirements. Prototypes should be updated to ensure that all revisions have been modelled. Further, specific user interface screens should be reviewed to check that all required user instructions are provided, that agreed terminology is used on all menu items and interface objects (e.g. checkboxes), and that the contents of drop down menus are complete. The user requirements document should be clearly linked to the prototype so that it is clear to Software Developers, how specific user requirements are executed in terms of the proposed HCI design model. Further, the 'to be' process map and future task descriptions which underlie the proposed technology concept might be updated.

9.10 Step 10: Handover of Requirements to Software Developers & Graphic Designers

Step ten involves the communication and handover of user requirements and the associated user interface design specification to both Software Developers and Graphic Designers. It is the task of the Software Developer to translate user requirements into functional requirements. Similarly, it is the task of Graphic Designers to translate the HCI and information design model into a full visual design – taking into account issues highlighted in relation to information priority and use and presentation of graphics including icons. Usually both user and design requirements are reviewed in person with relevant team members. Prior to this, HCI professionals may have provided advance feedback to the team, and so they may have a broad understanding of the proposed tool requirements. It is recommended that HCI professional involve other team members in the research as early in the process as is possible, to facilitate this handover.

9.11 Step 11: Review & Evaluation of Software Prototypes & Graphic Design

Step eleven involves the review and evaluation of software prototypes (with embedded graphic design), as these activities progress. Prototypes can be reviewed either with team members and/or with end users. In relation to the former, this typically takes the form of a walk-through and evaluation of prototypes with team members. It is important that the software prototypes cohere with the agreed HCI design specification. There may be problems which need to be resolved with the broader team. For example, the implementation of workflows as specified in the URD and associated prototypes may require more software development effort than planned. Alternative solutions may need to be agreed with the team. Further, a number of graphic design options may be suggested. As such, HCI professional may be required to assist Graphic Designers in terms of the selection of specific design options. Usually, the evaluation of prototypes with end users involves some form of user testing.

9.12 Step 12: Evaluation of High Fidelity Prototypes

Once the software prototypes are fully developed, HCI researchers can engage in additional user testing of the system.

9.13 Step 13: System Certification

Step thirteen involves the certification of the system. This is not applicable to all systems. If required, this follows established procedures detailed by the relevant authorities. Usually this process is conducted in parallel to many of the earlier HCI activities.

9.14 Step 14: Ongoing Feedback & Improvements, Post Go Live

The final step – also an optional step – involves the evaluation of the live system once it has been implemented in the organisation. A range of methods such as surveys, interviews and observations can be used. The output of this activity is an assessment of the systems usability and a specification of the re-design requirements for future development activities (if these are being undertaken). Usually any minor problems identified are corrected in the short term.

10. Practical Issues to Consider

In relation to the selection and application of specific methodologies, a number of practical issues must be considered. As mentioned previously, one of the key challenges facing HCI designers is identifying suitable HCI design methods. That is, identifying methods that facilitate work practice re-engineering/envisionment and the related development of user friendly work tools. This question is intensified if research is conducted as part of a commercial software project. Here, HCI activities are subject to constraints. Both research budgets and project time may be limited (product time to market is critical). This may necessitate concurrent HCI and software development activities. Also, HCI practitioners and management teams may have different views regarding research rigour and product quality. Management may want problems solved swiftly and not understand the iterative nature of HCI work and/or specific method limitations. In this environment, HCI practitioners must select methods which provide concrete design instruction/feedback so that products are developed both on time and within budget. HCI practioners working in research laboratories may face similar problems. The research plan may priortise software development activities and a limited budget may be dedicated to HCI research. Again, researchers may need to be opportunistic in terms of the choice and specific application of HCI methods, to ensure that the core brief is delivered on.

Certain of the HCI methodologies outlined above present more or less challenges in terms of time constraints linked to data capture and analysis. Firstly, process mapping activities are quite time consuming. The development of a robust process map requires considerable effort in terms of gathering data (e.g. conducting process workshops, interviews and observations of a range of stakeholders) and analysis and visualization of data (e.g. development of the process map). In most cases, it is not possible to develop a detailed process map for all processes. As such, it is recommended, that the researcher maps all the key processes and the key tasks of operational agents, at a high level. If time allows, the researcher might then explore those processes which are most critical to the technology development agenda, in more detail. The envisionment of future processes is best undertaken through collaborative future process envisionment workshops involving all key stakeholders.

Similarly, the scope of task analysis requires careful consideration. Before embarking on a task analysis, the researcher should review his/her specific objective and the required outputs. Is a detailed task model required? Or, is the advancement of task scenarios for critical tasks sufficient? It is imperative that task analysis activities focus on the primary user roles and key tasks. However, in the case of collaborative tasks, team task requirements must be considered. To obtain a true picture of team task activity and associated constraints, specific workflows must be modelled from the perspective of all agents involved in the

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activity. Depending on time and budget, it may not be possible to interview or observe all agents. As such, research must focus on those tasks where collaboration/co-ordination activity is most complex and requires re-design.

To develop a system model of task activities and associated processes - requires conducting research across different organisational processes and functions. In short, this necessitates recruiting a wide range of participants. Releasing personnel from the operation for user interviews or workshops can be costly. Companies are often most disposed towards methods that are least taxing on operations (e.g. preference for observations or short group workshops). Further, participants may be more or less willing to discuss their work and associated problems. Certain participants may be more 'highly involved' in the operation and motivated to improve both processes and technologies. Others may be resistant to change. It is important that the participant panel reflects a range of operational and organisational functions, such that future process and technology envisionment addresses a range of perspectives and the proposed solution is amenable to all.

11. Conclusions

Crucially, the introduction of new technologies follows from the envisionment of new or improved work processes and related task workflows. Proposed technology concepts must be derived in conjunction with end users. Further, the advancement of new or improved work technologies must be predicated on operational requirements and fit the organisational environment. Technology innovation should support operational and organisational goals, as opposed to been driven by new or innovative technical advances. Crucially, the development of new workplace technology affords the opportunity to rethink existing practices and tool support from a process redesign/improvement perspective.

Traditional HCI design methods are unsatisfactory in terms of task and technology envisionment in socio-technical contexts. A number of alternatives such as the application of participatory techniques (e.g. role play, envisionment exercises and collaborative prototyping) and scenario based design approaches have been proposed. Although useful, such methods do not take into account the broader process context and associated information flow which underlies operator task performance. To this end, a blended HCI methodological approach involving the integration of a range of methods is suggested. Drawing from two HCI studies in the Aerospace industry, a new blended HCI design methodology – involving the integration of a range of methodologies associated with two of the three Human Factors fields is advanced. This integrates both formal and informal HCI methods associated with Cognitive Ergonomics, with process mapping methods used in the Organisational Ergonomics domain. Collectively, the application of the above methods ensures that future work practices and technology solutions are properly embedded in the operational and organisational context.

It is argued that HCI designers cannot develop systems/technology without investigating broader work design issues (e.g. operational and organisational aspects of task performance). As such, there is a link between methodologies used both in the Cognitive Ergonomics and Organisational Ergonomics fields. To identify specific operator technology requirements, we must first develop a real world model of the overall operational and organisational system in which the operator works. Such an approach is not typically used

in the HCI field. Typically, HCI methods study user task workflows and technology/tool interactions in isolation from the broader operational and organisational processes and related information flow.

This chapter has reviewed a number of design steps in an overall user centred design process. It is suggested that HCI researchers follow this research design, albeit taking into account project constraints. To understand the relationship between task and process, some kind of process mapping is necessary. The advancement of a high level process map is better than none. This will help scope the direction of follow on task analysis – specifically in terms of the selection of tasks that are most complex in terms of process and/or task dependencies. The analysis of system information flow is also critical. The design of future task practices and tool design might be considered from an information flow perspective. As such, HCI activities might focus on identifying what information is relevant to the performance of a task or group of tasks, at a particular point in operational process/timeline, taking into account role of context. To this end, proposed tool concepts can be evaluated in terms of delivering on specific information requirements at certain points in operation, in an appropriate way (e.g. presentation and timing). Further, the application of a range of participatory methods (e.g. technology envisionment, role play, participative prototyping) is also necessary, both in terms of the envisionment and evaluation of future work practice and associated technologies, and the specification of user interface design features. Proposed design solutions must be both realistic from an organisational and technical perspective. As such, proposed work practice and technology concepts should be reviewed with relevant personnel to assess what is feasible. Although modelling the specific aspects of technology integration or broader organisational processes is not the remit of HCI designers, it is important that HCI Designers are mindful of these issues, and that the proposed design solution is advanced following appropriate discussion and negotiation in relation to this. Importantly, these issues need to be reviewed as early as is possible in the user centred design process, so that unnecessary time is not spent on concepts that are not possible for a variety of technical or organisational reasons. The early evaluation of proposed concepts in the form of implementation workshops with relevant stakeholders is useful here.

Evidently, task models and associated design solutions require justification. How can we be sure that the task picture and proposed tool concept is both valid and reliable? If the requirements for developing a valid task picture - as detailed earlier -are addressed, then this provides some degree of certainty. Critically, the application of process mapping techniques ensures that technology development is predicated on operational concepts and requirements. Further, the use of observational methods helps ensure high ecological validity. Moreover, the use of collaborative prototyping and evaluation techniques entails that end user constraints and requirements are factored into the design solution. This follows from the participatory design mantra of designing with end users and not just for end users. Also, this mitigates the task artefact lifecycle, as outlined by Carroll (2002). In addition, the use of implementation workshops ensures that proposed technology concepts are evaluated from a broader organisational and technology level. Lastly, recruiting a suitable panel of participants – representing the range of operational and organisational processes under consideration, is also important.

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Human Computer Interaction: New Developments

Edited by Kikuo Asai

The book consists of 20 chapters, each addressing a certain aspect of human-computer interaction. Each chapter gives the reader background information on a subject and proposes an original solution. This should serve as a valuable tool for professionals in this interdisciplinary field. Hopefully, readers will contribute their own discoveries and improvements, innovative ideas and concepts, as well as novel applications and business models related to the field of human-computer interaction. It is our wish that the reader consider not only what our authors have written and the experimentation they have described, but also the examples they have set.

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