Chapter 2: Analyzing Requirements

In this chapter we introduce the goals and methods of **requirements analysis**, the phase of software development in which the needs of clients with respect to a proposed project or technology are analyzed. Requirements analysis usually starts with a mission statement or orienting goals, then becomes more elaborate through studies and meetings with prospective clients. Under the waterfall model, the result is a **requirements specification**, a document that lists all functions and features that the proposed system must satisfy.

User-centered approaches to software development recognize that it is impossible to specify all requirements in advance. Clients cannot appreciate their real needs until they see what kinds of options are available; work practices naturally evolve as new technology is introduced. However, this does not mean that requirements analysis is impossible or unimportant, but simply that it must be seen as an ongoing process. Analysts must still develop a detailed understanding of clients, their current work practices, and their needs with respect to the technology under consideration. They must develop and convey a rich description of the problems and opportunities that could be addressed through software design and development.

Usability engineers participate in requirements analysis by studying how work currently takes place to see if they can identify problems or opportunities that might be addressed by new technology. This analysis provides crucial input to the design of new computing systems: At a minimum, a project team hopes to enhance the current situation. Of course other input will be provided by analyses that look at concerns such as hardware platforms, cost, development schedule, or marketing strategies. But because this book is about understanding and responding to the needs of users, we limit our discussion to concepts and methods for analyzing usage concerns.

2.1 Analyzing Work Practices

What is work?[1] Try asking yourself or a friend this question. You will probably come up with the things you do during a typical day, the objects or tools you work with, and perhaps the people you talk to. A description of work involves three dimensions:

- the **activities** of the workplace: What are the personal or organizational goals that individuals or groups pursue? What actions do they carry out to pursue these goals?
- the **artifacts** of the workplace: What information is retrieved or created in the course of carrying out work activities? What tools (computer based or not) are used to create and work with this information?
- the **social context** of the workplace: How are individuals and groups organized into larger structures? What roles are defined (implicitly or explicitly)? How do people depend on each other in achieving their goals?

Analyzing all of these aspects of work is complex. A popular approach for analyzing the first dimension (activities) is **hierarchical task analysis** (HTA): Individual tasks and subtasks are identified and organized into a hierarchy (Diaper 1989). A strength of HTA is the step-by-step transformation of a complex activity space into an organized set of successive choices and actions. The resulting hierarchy can be examined for completeness, complexity, inconsistencies, and so on. However, too much emphasis on task decomposition can be problematic (Tradeoff 2.1). An analyst can become consumed by representing task elements, step sequences, and decision rules. Tasks and subtasks must always be understood within the larger context of work; overemphasizing the steps of a task can cause one to miss the forest for the trees. Part of understanding what it means to review accounts at a bank is learning about the banking organization—who makes certain that accounts are up to date, who has access to various accounts, what happens once an account is reviewed, and so on.

TRADEOFF 2.1 Hierarchical task analysis documents the functional goals of a workplace, BUT may direct attention away from an organization's social relationships and goals.

The social context of work includes the physical, organizational, social, and cultural relationships that contribute to a work environment. Work activities do not take place in a vacuum. Tasks are motivated by personal goals; these in turn are motivated by the higher-level goals held by the organizations sponsoring the work (see "Activities of a Health Care Center" sidebar). A banker may report that she is

reviewing accounts, but the bank may view this as "providing customer service" or perhaps "increasing return on investment."

Of course, the banker is not the only person working toward this high-level goal. Secretaries, data-entry personnel, database programmers, even the bank's executives, work with the banker to meet the bank's business goals. They collaborate by communicating with each other about their personal activites, as well as through shared tools and information. Their interactions are shaped not only by the tools they use, but also by their shared understanding of the bank's business practices—its goals, policies, and procedures.

Another aspect of work analysis is the study of workplace artifacts. The tools that people use to carry out their tasks can provide considerable insight into how they do their work (Carroll & Campbell 1989). An artifact is simply a designed object—typical office artifacts include the furniture, writing instruments and supplies of various sorts, forms and lists, folders, shelves and cabinets for storage, ad computers and associated software packages (Figure 2.2). The features ofeach artifact encourage different kinds of actions and thoughts. For example, a pencil has a shape and weight compatible with the action ofholding it between two or more finges, sliding it across paper, and so on; the buttons on tape dispenser has a weight and sharp serrated edge to enable one-handed tearing of tape segments.

Figure 2.2: Photograph of a receptionist's desk at Virginia Tech. The desk and its surroundings hold a huge set of artifacts used in the employee's day-to-day activities.

It is easy and fun to find artifacts and analyze their characteristics (Norman 1987, 1988). Returning to the example of a pencil, note that its shape suggests quite a bit about human hands, such as their size and grasping behavior. Pencil designers succeed to a great extent by giving new designs the physical characteristics of pencils that have been used for years. But the artifact is just part of the picture. Even an object as simple as a pencil must be analyzed with respect to its real-world use (Tradeoff 2.2). Different uses of pencils bring out different concerns—elementary school students need good erasers; very sharp points are important to architects or graphic artists; and preteens competing for social status may care only about name-brand visibility. In the photograph above, the receptionist positions a wide variety of writing instruments in a visible and accessible location so that visitors will find and use the tools as needed.

TRADEOFF 2.2	Work artifacts reflect knowledge, roles, and procedures related to a task, BUT the actual meaning of an artifact is apparent only when observed in use.

Usability engineers have adapted some of anthropology's methods for analyzing the activities, artifacts, and social context of work. **Ethnography** is an analytical technique used by anthropologists to gain insights into the life experiences of people whose everyday reality is vastly different from the analyst's (Blomberg 1995). An ethnographer becomes intensely involved in a group's culture and activities, sometimes even joining the group as a participant-observer.

Activities of a Health Care Center

Activity theory offers a view of task analysis that emphasizes the goals and practices of a community (Bødker 1991; Nardi 1996). In this framework, an activity is comprised of three elements: a *subject* (the actor), the *community* in which he or she is operating, and the *object* of the activity (the goal). However, each of these elements is mediated by other features of the activity—the *tools* that support

the work, the *rules of practice* that define the conventions and procedures to be followed, and the *division of labor* that positions the goal of this activity within the community in general.

Kuutti and Arvonen (1992) exemplify this framework for a health clinic. The organization wanted to evolve from a highly bureaucratic organization with strong separations between its various units (e.g., social work, clinics, and hospital) to a more service-oriented organization. A key assumption was that different units share a common object—enhancing the "life processes" of the town's citizens. This object was understood to be a complex goal requiring the integrated services of complementary health care units.

Activity theory provides an analysis of individuals acting within this community—for example, a physician. Although the entire community shares the goal of patient care, the physician works in a clinic, which is analyzed as a subcommunity. This clinic is geographically and functionally separated from other units, like the hospital and social work office. His day-to-day behavior is mediated by the tools and the rules of practice of his subcommunity.

As a result, the physician has no way to integrate his efforts with the work done by health care workers in the other subcommunities. For instance, he cannot benefit from the work on home life carried out by a social worker, or psychiatric treatments. There is a mismatch between the high-level shared goal and the physical working conditions. In activity theory, this mismatch is raised as a *contradiction* that must be resolved before the activity can be successful. In this case study, a more comprehensive analysis of "community" was needed. Email and telephone were used to foster a new virtual community, bringing together workers from different health units.

In the HCI community, ethnography involves observations and interviews of work groups in their natural setting, as well as collection and analysis of work artifacts (see "Teamwork in Air Traffic Control" sidebar on pages 44–45). These studies are often carried out in an iterative fashion, where analysis of one set of data raises questions or possibilities that are pursued in follow-up observations and interviews. However, a full ethnographic study implies weeks or months of observation, and system development projects rarely have this luxurious a schedule. In practice HCI professionals often rely on "quick-and-dirty" ethnographies—these field studies are carried out in a more intensive and focused fashion, with the goal of learning just enough to guide subsequent design activities (Nardi 1997; Hughes, et al. 1996).

[1]In this discussion we use "work" to refer broadly to the goal-directed activities that take place in the problem domain. In some cases, this may involve leisure or educational activities, but in general the same methods can be applied to any situation with established practices.

2.2 Getting Users Involved

Who are the users? This is obviously an important question in user-centered development. It is first raised during requirements analysis when a project team needs to decide whose activities to study. Managers or corporate executives are a good source of high-level needs (e.g., reduce data-processing errors, or integrate billing and accounting). These individuals may also have a coherent view of many workers' responsibilities and of the conditions under which tasks are completed. Because of the hierarchical nature of most organizations, these people are easy to identify and comprise a relatively small set. But if a requirements team stops there, they will miss the more detailed and situation-specific needs of the people who will be using the new system (Tradeoff 2.3).

TRADEOFF 2.3 Experienced workers have detailed knowledge about a task's context and operation, BUT people in related roles may have completely different understandings.

Requirements analysis must consider multiple **stakeholders**—the many different groups of people who will be impacted by the development of the system (Checkland 1981; Muller 1991). Managers authorize the purchase or development of a new computer system; workers with various job responsibilities use the system; and other employees may benefit or suffer indirectly. Each set of stakeholders has motivations and problems that a proposed system may address (e.g., productivity, satisfaction, or ease of learning). None of them can adequately communicate the perspectives of the

others—as summarized in the law office sidebar, many details of a subordinate's work activities and concerns are simply invisible to those in supervisory roles. Requirements analysis must bring the full range of stakeholder groups into the observation and interviewing activities.

But do people even understand their own activities? We made the point earlier that too much focus on the steps of a task can cause analysts to miss important workplace context factors. A similar point holds with respect to interviews and discussions. People are remarkably good (and reliable) at "rationalizing" their behavior (Ericsson & Simon 1993). Thus, if asked, workers describe the prescribed or most typical version of a task. If a "procedures manual" or other policy document exists, task descriptions may mirror the official procedures and policies.

Teamwork in Air Traffic Control

An ethnographic study of British air traffic control rooms by Hughes, Randall, and Shapiro (1992) highlighted a central role for the paper strips used to chart the progress of individual flights. In this study the field-workers immersed themselves in the work of air traffic controllers for several months. They observed the activity in the control rooms and talked to the staff, and they also discussed with the staff the observations they were collecting and their interpretation of these data.

The goal of the study was to analyze the social organization of the work in the air traffic control rooms. The researchers showed how the flight progress strips supported individuation—the controllers knew what their jobs were in any given situation, but also how their tasks were interdependent. This division of labor was accomplished smoothly because the controllers had shared knowledge of what the strips indicated; they were able to take on and hand off tasks as needed, and to recognize and address problems that arose.

Each flight strip displays identifying information about an aircraft, its flight plan, and its current status (see figure on facing page). However, these artifacts are more than just information displays. The strips are *work sites*, used to initiate and perform control tasks. Each strip is printed from the online database, but then annotated as flight events transpire. This creates a public history, so that any controller can reconstruct a "trajectory" of what happened with the flight. The strips are used along with radar data to spot exceptions or problems with standard ordering and arrangement of traffic. Individual strips get "messy" to the extent flights have deviated from the norm; thus, a set of strips serves as a sort of proxy for the orderliness of the skies.

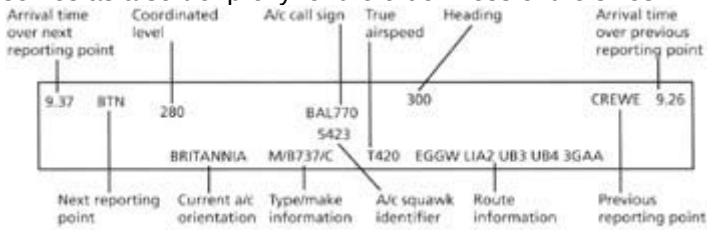

Diagram of the flight strip studied by Hughes, Randall, and Shapiro (1992, 117).

The team interacts through the strips. Once a strip is printed and its initial data verified, it is placed in a holder that is color coded for its direction. It may then be marked up by different controllers, each using a different ink color; problems or deviations are signaled by moving a strip out of alignment, so that visual scanning detects problem flights. This has important social consequences for the person responsible for a flight. This individual knows that other team members are aware of the flight's situation and can be consulted; who, if anyone, has noted specific issues with the flight; if a particularly difficult problem arises it can be passed on to the team leader without a lot of explanation; and so on.

The ethnographic analysis documented the complex tasks that rely on the flight control strips. At the same time it made clear the constraints of these manually created and maintained records. A particularly compelling observation was *trust* of the strips. This was due not to the strips' physical characteristics, but rather to the social process they are part of—the strips are public; and staying on top of each other's problem flights, and discussing them informally while working or during breaks, is simply taken for granted. Any computerized replacement of the strips must support not just management of flight information, but also the social fabric of the work setting that makes the controllers confident of the information around them.

However, this officially blessed knowledge is only part of the picture (Tradeoff 2.4). Experienced workers also possess much "unofficial" knowledge, learned when dealing with the specific needs of different situations, exceptions, particular coworkers, and so on. This expertise is often held as **tacit knowledge**—experts may not even realize what they "know" until confronted with their own behavior or interviewed with situation-specific probes. Tacit knowledge about work is often very valuable, because it may contain the "fixes" or "enhancements" that have developed informally to address the problems or opportunities of day-to-day work.

TRADEOFF 2.4 Documented standard procedures make work smooth and stress free, BUT much of an employee's value comes in the tacit recognition and resolution of exceptions.

Sachs (1993, 1995) suggests that organizations can understand themselves from two different perspectives—an "organizational, explicit" view and an "activity-oriented, tacit" view (Table 2.1). The organizational view is easy to reveal and document, because it is described in company policies and procedures. For example, a **workflow system** is a business support system that models explicit task knowledge of this sort. The business process model is then used to plan, coordinate, and track interrelated tasks. In contrast, understanding the second perspective requires the study of everyday work processes to see what employees actually do to make their organization function effectively. This often involves the analysis of informal and ad hoc communication and collaboration activities (see "Tacit Knowledge in Troubleshooting" sidebar).

Table 2.1: Contrasting an organizational, explicit knowledge view with an activity-oriented, tacit knowledge view (after Sachs 1995, 38).

Organizational Explicit View	Activity-Oriented Tacit View
Training	Learning
Tasks	Know-how
Position in hierarchy	Informal political systems, network of contacts
Procedures and techniques	Conceptual understanding
Work flow	Work practices
Methods and procedures	Rules of thumb, judgment
Teams	Communities

One technique for probing workers' conscious and unconscious knowledge is **contextual inquiry** (Holtzblatt & Beyer 1993). In this method, people are observed as they carry out tasks in their normal work environment. Notes are made, but the observers are also free to interrupt the work if a problem arises, or to ask for elaboration or rationale for people's actions. For example, an analyst might see a secretary stop working on a memo to phone another secretary, and then ask her after the call to explain what happened between her and her coworker. This creates a more elaborate record of the task (e.g., it may actually involve input from two employees). It also helps in identifying the *causes* of people's behavior, because they are prompted to reflect on their actions at the time that they take place.

A related approach is **participatory analysis**, where people are observed during normal work activities, and later engaged in discussion about these activities. During requirements analysis for the Virtual School (Chapter 1), we videotaped many hours of students conducting science experiments in their classrooms. Later on, we shared these videotapes with small groups of teachers and students. We asked them to suggest interesting features of the activities, and to help us understand why activities worked well or poorly, and what might be done to improve the learning outcomes (Chin, Rosson, & Carroll 1997).

Tacit Knowledge in Troubleshooting

People often see their conversations with coworkers as a social aspect of work that is enjoyable but unrelated to work goals. Sachs (1995) discusses the implications of this in her case study of telephony workers in a phone company. The study analyzed the tasks of detecting, submitting, and resolving problems on telephone lines. The impetus for the study was the Trouble Ticketing System (TTS), a large database used to record telephone line problems, assign problems (tickets) to engineers for correction, and keep records of problems detected and resolved.

Sachs argues that this system embodies an organizational view of work, where individual tasks are modular and well defined: One worker finds a problem and submits it to the database; TTS assigns it to the engineer at the relevant site, and that engineer picks up the ticket, fixes the problem, and moves on. The original worker is done with problem analysis after submitting the ticket, the second can move on once the problem has been addressed, and so on. TTS replaced a manual system in which workers contacted each other directly over the phone, often working together to resolve a problem. The system was designed to make work more efficient by eliminating unnecessary phone conversations.

In her interviews with telephony veterans, Sachs found that the phone conversations were far from unnecessary. The initiation, conduct, and consequences of these conversations reflected a wealth of tacit knowledge held by the engineers—selecting the right person to call (with relevant expertise for the problem), the "filling in" on what the first worker had or had not determined or tried to this point, sharing of hypotheses and testing methods, iterating together through tests and results, andcarrying the results of this informal analysis into other possibly related problem areas. In fact, TTS had made work *less* efficient in many cases, because in order to doa competent job, engineers developed "workarounds" wherein they used phone conversations as they had in the past, and then used TTS to document the process afterward.

Sachs noted that the telephony workerswere not at first aware of how much troubleshooting knowledge they were using in their jobs. They described tasks as they understood them from company policy and procedures. Only after considerable data collection and discussion did they recognize that their jobs included the skills to navigate and draw upon a rich organizational network of colleagues. In further work, Sachs helped the phone company to develop a fix for the observed workarounds in the form of a new organizational role: a "turf coordinator," a senior engineer responsible for identifying and coordinating the temporary network of workers needed to collaborate on troubleshooting a problem. As a result of Sachs's analysis, work that had been tacit and informal was elevated to an explicit business responsibility.

Summary and Review

This chapter summarized some of the important issues in analyzing the needs of the situation a system will transform. The virtual science-fair case study was introduced and used to illustrate requirements analysis activities in SBD. Central points include:

- A work setting must be analyzed from the perspective of diverse stakeholders, and work activities must be observed in their real-world context, to be fully understood.
- The objects and materials (artifacts) of a workplace can provide insights into work processes that are often only understood tacitly by individual workers, or that are distributed across many elements of a work setting.
- To gain the most from field studies, it is critical to plan in advance the questions to be asked, what and how data will be collected, and how a comfortable exchange between analysts and work participants will be ensured.
- Field notes, workplace artifacts, and videotapes or other interview records should be examined for general patterns (themes) in stakeholder characteristics, task or procedure structure, and the information required or assumed by tasks.
- Problem scenarios synthesize a range of workplace needs and opportunities, with an emphasis on typical or critical issues uncovered through stakeholder, artifact, and theme analysis.
- A claim hypothesizes a relation between a feature of a situation and the likely positive or negative consequences for actors in the situation; claims document tradeoffs that may be addressed by future design work.