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# Modelling the Requirements Process: where are the people?

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**Abstract**

*This paper reports the outcomes of a three year study into the requirements process, an important but poorly understood part of systems development. Humans play an essential role in determining requirements yet few models of the requirements process include human actors. This paper presents an understanding of the requirements process expressed in a descriptive model that integrates the social and technical aspects of the requirements process. The model comprises five key areas: the problem domain, analysts' domain, requirements sub-processes, problem space and management of the requirements process. The model may be used to support, manage and improve the requirements process in practice.*

**Keywords**

Requirements process; systems analysis; process modelling; field research

## INTRODUCTION

Process models express understanding of a process as the basis for examining, analysing and diagnosing processes (Lott and Rombach, 1993; Pfleeger, 1998). Process models may be used as a foundation for process improvement programs, the design of tools and techniques to support the process, and the construction of methods to manage the process. The focus of this paper is models of the requirements process. The requirements process "is about people, about communications, and about attempting to understand before attempting to be understood" (Davis, 1998:6). People are an essential part of the requirements process: requirements are constructed by people through interpersonal interaction. Yet when the requirements process is modelled, human actors are rarely represented (see Davis, 1993; Kotonya and Sommerville, 1998; Macaulay, 1996; Pfleeger, 1998; Wieringa, 1996). It appears that, when trying to represent the requirements process, modellers have abstracted away a crucial component of the process and therefore hindered integration of social issues into the requirements process. This in turn has impeded efforts to improve the requirements process. This paper presents an understanding of the requirements process expressed in a model that integrates both social and technical aspects of the requirements process. The model may be used to support, manage and improve the requirements process in practice.

The process by which requirements are determined is an important part of developing information systems (IS). It lays the groundwork for all subsequent development efforts because identifying the underlying problem is necessary to 'build the right system' (see Drucker, 1967). Significant effort—up to 75% of their time— is spent by analysts on problem definition (Vitalari, 1981): this is a major, but poorly understood, aspect of systems development (Bubenko, 1995; Jirotka and Goguen, 1994; Loucopoulos and Karakostas, 1995). Extensive work has been undertaken to develop tools, techniques and methods to improve the requirements process. However, developing tools, techniques and methods without sound understanding of the requirements process in practice suggests that these improvement efforts may be misdirected (Lindland, Sindre and Solvberg, 1994).

The requirements process transforms information about a problem situation into understanding of needs that may be expressed in a documented form. Although there is agreement about what is transformed by the requirements process (see Pohl, 1993), there is very little understanding of how this is achieved. The requirements process involves creative and cognitive work (Kotonya and Sommerville, 1998) and provides few visible markers with which to trace its progress. Practising analysts appear unable to describe how they transform stakeholders' needs into a formal specification document (Lubars, Potts and Richter, 1993). Similarly, IS researchers have "only the beginnings of an understanding of how requirements are actually constructed and used" (Jirotka and Goguen, 1994:3). The research reported in this paper describes how the requirements process is performed in practice. It focuses on the early stages of the requirements process where exploring a problem situation and stakeholders' needs is undertaken. The outcome is a generic model of the requirements process that reflects professional practice and is sufficiently detailed to communicate common understanding about the process, identify problem areas and enable the design and application of appropriate improvement strategies.

The paper begins with an outline of the research approach. In the following section, a descriptive model of the requirements process is presented. The model comprises five key areas that are described with references to the cases studied in the research. The model is then evaluated according to three criteria and its contribution to modelling and understanding the requirements process as the basis for practical improvements is indicated. In conclusion, it is suggested that the model, in integrating both social and technical aspects of the early stages of the requirements process, makes a valuable contribution to the study of the requirements process.

## THE RESEARCH APPROACH

The research was undertaken using structured-case (Carroll and Swatman, 2000), a research approach constructed as part of this study to build theory from interpretive field research. Structured-case guides the research process, enables a researcher to record the dynamics of the research and establishes the links between the research themes, the data, the analysis and the findings. It helps to ensure the soundness of the research and the plausibility of the reporting of the findings. Structured-case features an initial conceptual framework (CF1 in Figure 1) and a process model of planning, collecting data, analysing the data and reflecting on the outcomes. As a result of this reflection, the conceptual framework is revised (CF2 in Figure 1). The revised conceptual framework is then used as the basis of another cycle of planning, collecting and analysing data and reflecting on the outcomes. Thus, each cycle through the process model results in an updated conceptual framework (CF2, CF3 … CFn), as shown in Figure 1.

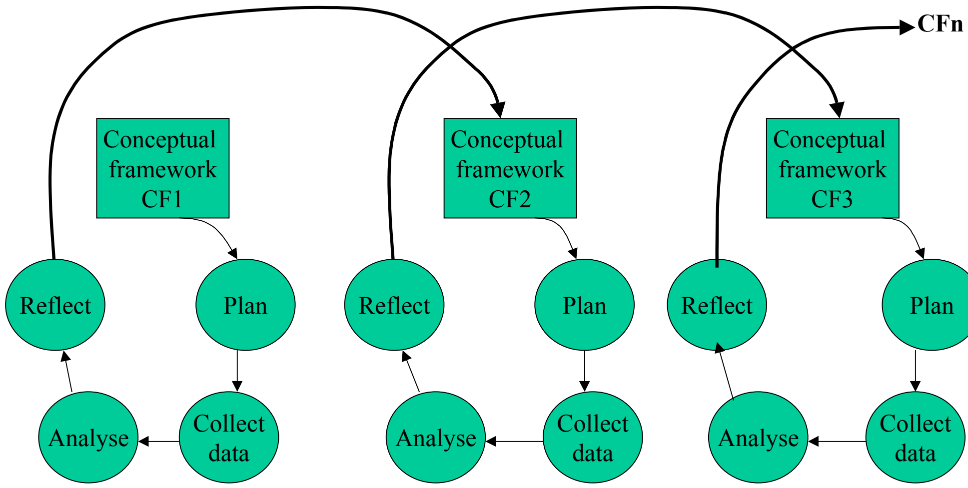


Figure 1: Multiple research cycles in structured-case

In this research, the initial conceptual framework (adapted from Carroll and Swatman, 1997:465) was synthesised from the literature; the synthesis enhanced the requirements framework of Loucopoulos and Karakostas (1995:21) with social and contextual details. As shown in Figure 2, the initial conceptual framework represents stakeholders within the problem domain and the three requirements sub-processes (elicitation, representation and validation) through which models and requirements are developed.

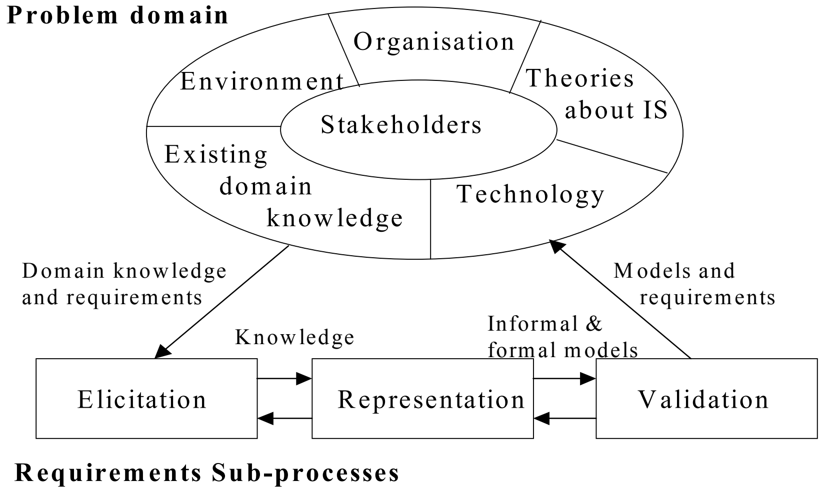


Figure 2: The initial conceptual framework, CF1

The initial conceptual framework formed the starting point of an intensive program of field research that was undertaken between 1997 and 1999. It was compared with the findings from the first field study and significant differences were observed (Carroll and Swatman, 1998). The initial conceptual framework was revised: the Problem Domain and the Requirements Sub-Processes were modified and the Analyst Domain was added. Consequently, a further three field studies were used to sequentially build knowledge about the early stages of the requirements process. Data were collected in all four cases using a combination of document analysis, observation, participant observation and interviews and analysed using coding derived from the current conceptual framework (see Carroll and Swatman, 2000).

The cases were selected using conceptually-driven sampling (Miles and Huberman, 1994); this involves selection of cases because of their individual characteristics rather than their representativeness of a class of cases. Each case was chosen to examine specific areas of the requirements process. The Information Broker case (Carroll and Swatman, 1998) involved an analyst and his assistant in problem definition and requirements gathering for a web-based information broker. The primary research method was observation of ten sessions lasting an average of two hours each. The Systems Section case (Carroll, 1999) focused on the internal IS department of a large manufacturing company. Multiple requirements processes for in-house systems development including electronic commerce, Computer-Aided Design/Computer-Aided Manufacture (CAD/CAM) and installation of Enterprise Resource Planning (ERP) systems were studied. Single analysts and small teams were examined; data were collected primarily from interviews with nine analysts and five managers and participant observation of four meetings. The Library case (Carroll, 2000b) featured two consultants facilitating the expression of requirements for a management information system for a large, multi-campus library. The primary research method was observation. The CARE case (Carroll, 2000a; Carroll and Swatman, 1999) involved in-depth fieldwork examining a feasibility study for a large government department. A multi-disciplinary team of seven consultants investigated the needs of heterogeneous stakeholders. Data were collected primarily using participant observation from twenty-three meetings and interviews involving forty-five people. The findings from the CARE case supported previous observations and provided small incremental gains in understanding of the requirements process. It appeared that theoretical saturation (Strauss and Corbin, 1990) was reached and so this was the last case studied.

## AN INTEGRATED MODEL OF THE REQUIREMENTS PROCESS

A total of seven cycles through the structured-case process model were undertaken (Carroll, 2000b). The final conceptual framework, a descriptive model that integrates understanding of the requirements process from the literature and knowledge built from the empirical research, is described in this paper and shown in Figure 3. We have called it the integrated model of the requirements process.

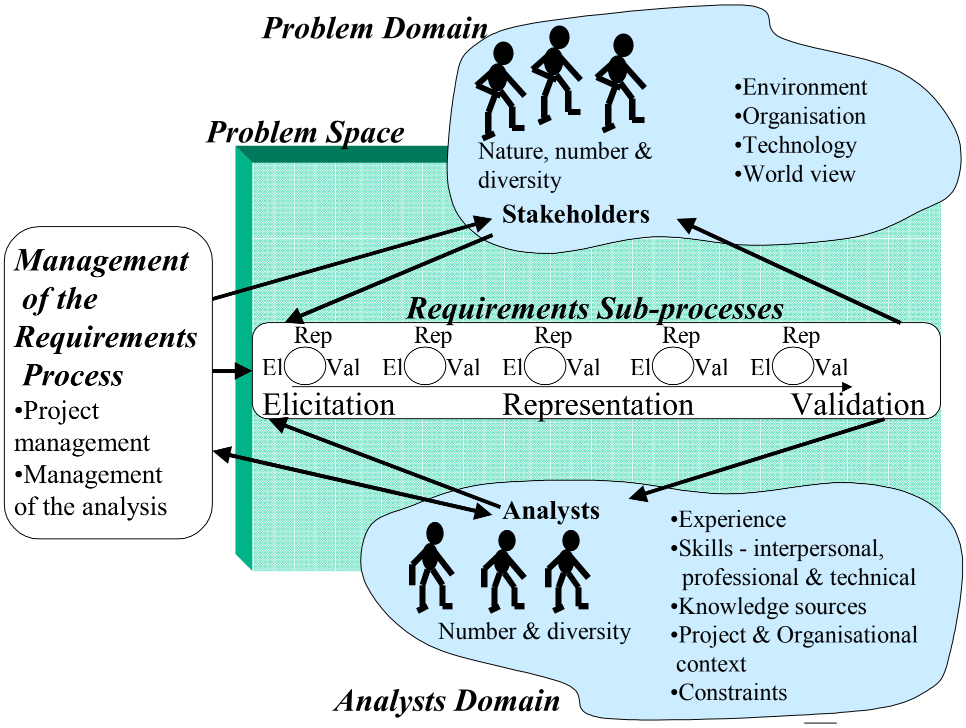


Figure 3: The integrated model of the requirements process

A model is an abstract representation that excludes much detail. The outcomes of analysing rich, qualitative data cannot be presented fully in a single model. However, the integrated model – together with the accompanying textual descriptions – represents the principal understanding that has been built about the requirements process. It includes the five key areas of the process – the Problem Domain, Analysts Domain, the Requirements Sub-Processes, the Problem Space and Management of the Requirements Process – and the relationships between them. The importance of people is made explicit in the model (humans are represented pictorially). The model shows the requirements process as interaction between the analysts and the stakeholders in context. The interaction takes the form of the elicitation, representation and validation sub-processes that are used to explore and define the problem space and consequently derive the requirements. This interaction must be managed. The understanding built about these areas of the requirements process is presented below, supported by examples from the four cases examined in the research.

### The Problem Domain

The Problem Domain has two aspects: the stakeholders and their context. The nature, number and diversity of stakeholders influenced the interaction in the requirements process: for example, whether the analyst was working with a small number (Information Broker case) of relatively homogenous stakeholders (Library case) or a large number of stakeholders (Library and CARE cases) having divergent or conflicting viewpoints (Systems Section and CARE cases). The nature of the stakeholders ranged from well-educated and articulate (Information Broker, Library, some of the Systems Section and CARE cases) to poorly-educated and inarticulate (some of the Systems Section and CARE cases). The elicitation techniques, style of interaction, time spent on elicitation and management of the interaction were tailored for the characteristics of the stakeholders.

The Problem Domain includes the organisational and competitive context in which the new system will operate (Guindon, 1990; Loucopoulos and Karakostas, 1995). We argue that the needs of the stakeholders can only be understood *within context*, that is, within the range of influences that shape their needs. The influences of the larger environment in which an organisation operates includes government policy, legislative requirements and economic factors. In this research, a more powerful influence was that of the organisation such as its business rules, culture, values, politics, and work practices.

The importance of interacting with stakeholders within their organisational context was clear in all but the first case (which was a market-driven rather than customised system). In the Systems Section case, one analyst described how he took time to observe users and chat with them in order to understand their situation and work practices. The analysts tried to access the stakeholders' worldviews: their views of their work, the proposed system and of technology generally. In the CARE case, the impracticality of the client's favoured solution became apparent when observing the organisational context in which services were provided: entering into the customers' world made this much clearer than the verbal descriptions of the users (Carroll, 2000a). In the only case where intermediaries provided information (the CARE case), their understanding was inaccurate and insufficient; it seems that direct interaction with a range of stakeholders is especially important in complex organisational situations where human, social and contextual issues are significant.

Less powerful influences within the Problem Domain were technology and the stakeholders' worldviews. Technology included the capabilities of existing technology (Information Broker and CARE cases), available technology within the organisation (all cases) and stakeholders' knowledge about technology (which posed difficulties in the Information Broker and CARE cases). The worldviews or the attitudes and perceptions of the stakeholders in the requirements process were a minor influence.

**Analysts Domain**

The Analysts Domain represents analysts and their context. Inclusion of analysts *within* the requirements process reflects the observation that it is not an activity performed by analysts but rather that analysts are an essential *part* of the requirements process.

The number and diversity of analysts in a requirements team influences the process. In three of the cases (Information Broker, Systems Section and the Library), small teams of analysts were studied. The CARE case was unusual as it involved a requirements team containing seven members from different disciplines (requirements engineering, electronic commerce and sociology) and organisations. This raised issues of co-ordinating team members and sharing their understanding of the information collected.

The practices of analysts can be understood in relation to their experience, skills, sources of knowledge and the context in which they operate. Most of the analysts were very experienced, having more than ten years experience. The effect of experience on analysts' practices was illustrated in the CARE case where an experienced analyst was observed along with the project manager who acted as analyst in several information gathering sessions. There were marked differences in the strategies used, the processing of the information gathered and the ability to conceptualise the problem.

Common types of skills included interpersonal, professional and technical skills. In all the cases, requirements were developed through a process of person-to-person interaction and so the analysts required excellent interpersonal – also called social or behavioural skills (Curtis, Krasner and Iscoe, 1988; Davis, 1998). Intensive interaction with stakeholders (Systems Section and CARE cases) and between members of the requirements team (CARE case) were noted. The importance of interpersonal skills such as communication, teamwork and an ability to engage stakeholders and facilitate different styles of interaction was observed.

A range of professional skills (cognitive, organisational and discipline-specific skills necessary for performance as a competent analyst) was observed. Cognitive skills relating to analysing and solving problems were needed. The importance of understanding business terminology, rules and priorities was noted. Also, there was little use of representation or modelling (see below). One surprising outcome of the research project was the relatively minor role of technical skills in the requirements processes observed. This may be explained in part by the focus on the early stages of the requirements process. Technical skills helped the analysts to ask pertinent questions, identify relevant information and develop a suitable solution when the problem space was defined (Information Broker, Systems Section and CARE cases). Familiarity with the technical aspects of IS as well as knowledge of hardware, software and telecommunications trends were elements of expertise in analysis although – given the importance of interpersonal interaction noted above – not sufficient on their own.

In all four cases studied, the analysts made little use of external knowledge sources about the type of problem, application or context in which the system would operate. Although knowledge may be available through personal networks, practitioner or academic literature or specialist consultants, these were not accessed. The majority of knowledge was gained through immersion in the problem domain and interaction with stakeholders. The influence of context on analysts' practices was less powerful than on stakeholders. This may be attributed to the involvement of consultants in three of the cases. Contextual influences on analysts included the organisation (Systems Section case) and the project, especially in relation to pressures arising from work as a consultant (Information Broker, the Library and CARE cases). Constraints of time (all cases), access to key stakeholders (Systems Section and CARE cases) and resources (Systems Section case) were noted.

**The Requirements Sub-Processes**

The requirements process was partitioned into three sub-processes: elicitation, representation and validation (Carroll and Swatman, 1997; Loucopoulos and Karakostas, 1995). Most of the observations were of the elicitation sub-process, although descriptions of all the sub-processes were gained in the Systems Section case. Interaction between the analysts and stakeholders occurred through eliciting information and validating the analysts' understanding. Both the stakeholders and analysts have input to this interaction: this is shown by the arrows feeding into the sub-processes in Figure 3. It is a negotiated (Information Broker and some of the Systems Section cases) or cooperative (Library, CARE and some of the Systems Section cases) activity characterised by control (Information Broker and Library cases), exchanges of information and advice (Information Broker and Library cases) and resolution of tension between focus and participation (Library case).

One unexpected finding was that very little representation or modelling was observed. This finding is not unique. It has been noted previously that some projects do not produce any specifications and that the emphasis on modelling may be misplaced as "*There is more to requirements analysis and design than drawing diagrams*" (Lubars, Potts and Richter, 1993:13). Substantial amounts of information were accumulated and organised during the requirements processes observed. It was expected that analysts would represent this information diagrammatically as a way of reducing and understanding it and communicating its key aspects to other team members. In this research, however, it appeared that analysts organise information using mental models, rather than physical representations, that are the basis for validating their understanding with the stakeholders. The primary output of all the requirements processes was understanding of the problem situation which in some cases was documented in an informal (the Systems Section case) or semiformal (the CARE case) way. Building understanding – rather than representing it – has been described as a major difficulty of software development (Brooks, 1987; Davis, 1998). The importance of understanding has implications for staffing IS projects. Continuity of personnel beyond the early stages of the requirements process is strongly advised so that the rich, contextual understanding of the problem domain is not lost.

A second finding about the Requirements Sub-Processes was that a number of iterations of elicitation, representation and validation occurred throughout an information gathering session. We have termed these 'mini-cycles'. The pattern observed was elicit, elicit, elicit information then periodically validate a chunk of information (Carroll and Swatman, 1998); representation was inferred from the organised summaries of information used for validation rather than directly observed. Mini-cycles of elicitation, organisation of information and validation were repeated throughout the elicitation sub-process (Information Broker and CARE cases) and development (Systems Section case). The mini-cycles describe the analyst-stakeholder interaction at a lower level of abstraction than the sub-processes. Therefore, it appears that there are two levels of granularity in the interaction: the mini-cycles and the partitioning of the overall requirements process. The operation of two parallel, iterative cycles may explain the observation that designers' activities are "*highly iterative, interleaved, and loosely ordered*" (Guindon and Curtis, 1989:266): there is iteration both within and between the Requirements Sub-Processes.

### Problem Space

Inclusion of the Problem Space in the model represents the exploration and definition of the problem situation that was observed in the requirements processes. It also addresses the omission of problem solving from software development models noted by Curtis, Krasner and Iscoe (1988:1269).

There are two important issues related to the problem space: the need to define the problem space and the way that this definition is achieved. Typically, in the complex types of requirements processes found in information systems, the problem is poorly understood (Bubenko, 1995; Loucopoulos and Karakostas, 1995). Exploring, bounding and defining the problem is a major challenge of the early stages of the requirements process. In the integrated model, the problem space is represented as lying beneath the problem and analyst domains and the three requirements sub-processes: the problem space is created through interaction (elicitation, representation and validation) between the analysts and stakeholders as well as other sources of knowledge such as documents and existing systems.

It was observed that understanding the problem is an early task that is seen as essential by all of the analysts studied. Only by working together in a joint learning process can the stakeholders and analysts develop understanding of the nature of the problem so that the 'right' system is developed. Significant time was spent 'digging deeper' to understand the nature of the underlying problem. In two of the cases – the Information Broker and CARE cases – the clients were focussed on solutions not the problem.

In the integrated model, the Problem Space is represented as three-dimensional (see also Pohl, 1993). This is to make explicit the observation that exploration of the problem space is opportunistic and unpredictable rather than linear or incremental as may be inferred from two-dimensional representations (Carroll and Swatman, 1998; 1999). The analysts appeared to explore issues, and thus fragments of the problem, rather than follow an orderly plan or pursue goals. Investigating different parts of the problem at different levels of abstraction was an integral part of the process; this has previously been noted in software design (Guindon, 1990). The only exception was in the CARE case when the project manager acted as analyst. She was inexperienced in analysis and her exploration of the problem space was linear and goal directed rather than opportunistic. It also appeared to be inefficient.

The analysts accumulated information as they explored the problem space. Definition of the problem was achieved through insight, where the problem space was reconceptualised, followed closely by a suggested solution. This is illustrated in the Information Broker case where the insight that the required system was data driven and that there was no processing structure needed led the analyst to comment: "*It's quite a simple little system*" followed a short time later by "*A basic database is all we need*." The operation of insight was unpredictable: it occurred through spontaneous restructuring of the problem space rather than methodical decomposition and synthesis. This observation contradicts the traditional view of problem analysis (Davis, 1993) whereby a problem is decomposed into smaller problems that are resolved and synthesised to construct a solution. The only decomposition observed was at a high level (Information Broker and Library cases). In the Information Broker case the problem was solved through analogical thinking or integration of problem fragments through insight and recognition of similarities with previous problems (Vitalari, 1981).

### Management of the Requirements Process

The term 'management of the requirements process' is used to describe the management activities that are performed during the process (Carroll and Swatman, 1999). It was noted as an important issue in the first case – the Information Broker – and refined through the remaining cases. This is an area that has received little attention from researchers. In the final research cycle, the activities involved in managing the requirements process were classified as either project management or management of the analysis. Project management includes planning and managing the project, the sequence of activities and allocation of resources (people, time, costs and equipment), identifying and liaising with key stakeholders and integrating this process with the other development processes. Management of the analysis includes managing the face-to-face interaction with stakeholders, exploration of the problem space and presentation of the information gathered. In the Information Broker and some of the Systems Section cases, both the project management and management of the analysis were performed by the analyst[1]. In the other cases involving more participants, these two functions were performed by different people. Separation of these management functions led to slow progress in the Library case and difficulties in communicating understanding and synchronising problem solving in the CARE case.

## DISCUSSION

A major outcome of the research is a model that represents the five areas of the requirements process. Although the integrated model cannot convey all the richness of detail accumulated, it does indicate the principal findings about the requirements process. Comparison of the integrated model with the initial conceptual model illustrates the contribution of the research: the scope of the model is greatly increased to include analysts and their context (Analysts Domain), the importance of opportunistic behaviour and problem solving (Problem Space) and management of the requirements process; human actors are included – they are represented by stick figures – to make explicit the importance of people to the process; and increased understanding of the interaction between analysts and stakeholders is evident in mini-cycles of elicitation, representation and validation (Requirements Sub-Processes). Although understanding of aspects of these five areas of the requirements process is available individually, it has not been brought together into a comprehensive model of the process. Similarly, the importance of some of the findings is implicit in various Information Systems Development (ISD) methodologies constructed to support the overall systems development process. ISD methodologies such as ETHICS (Mumford and Weir, 1979) and Multiview (Avison and Wood-Harper, 1990) aim to combine the social and technical aspects of systems development while Joint Application Development (JAD) (Wood and Silver, 1989) encourages developer-user interaction. However, the significance of this research is to make these aspects explicit and represent them in a single model, with a focus on requirements rather than the overall systems development process.

The findings have implications for practice as well as research. The integrated model may be used to support, manage and improve the requirements process. Understanding how analysts *actually* work rather than how they *should* work facilitates the design of artifacts to support real-life practices, provide structure for their work and then enable them to progress towards improved professional practices. The integrated model provides a sound basis for constructing a process improvement program for the early stages of the requirements process including the design of tools, techniques and methods and the development of professional and interpersonal skills.

The integrated model can be evaluated using three principles: partitioning, abstraction and projection (Davis, 1993). The integrated model *partitions* the requirements process as a process in its own right and its *level of abstraction* is high enough to provide insights into the process in practice as a whole. In addition, the granularity of the model is sufficiently fine to enable identification of areas for improvement as part of a process improvement program. This addresses concerns (Bubenko *et al.*, 1994) about whether it was possible to derive a useful model of the requirements process that can be broadly applied. The integrated model

[1]For this reason, management of the requirements process is not represented by a stick figure. This role does not necessarily involve additional people in the requirements process.

has demonstrated that it *is* possible and that the model *will* act as a foundation for improving the requirements process (see Carroll, 2000b; Carroll and Swatman, 1999).

The *projection* of the model is unusual. The integrated model provides an outsider's view of the requirements process, its areas and the influences on it. However, incorporated in this model is the ability to view the process through an additional three viewpoints. The interfaces between the stakeholders, the analysts and the managers and the rest of the process are clear. For managers, the integrated model can act as a contingency model and enable effective estimation, resource allocation and risk assessment for the requirements process. For analysts, the integrated model highlights the major issues that will need to be addressed (interaction with stakeholders and their context, exploration of the problem space, management of the project and the analysis as well as the factors within each of these areas). For stakeholders, the integrated model provides an overview of the key people, activities and interactions in the requirements process. Therefore the integrated model incorporates multiple projections of the requirements process in the way that the Layered Behavioral Model (Curtis, Krasner and Iscoe, 1988:1269) incorporates multiple projections of the software development process. This evaluation of the integrated model indicates that it represents a significant contribution to modelling and understanding of the requirements process as well as providing the basis for improvements to requirements practice.

## CONCLUSION

Reflection on the integrated model suggests that the early stages of the requirements process have been misconceived in the literature. The implications of the understanding represented in the integrated model are that the early stages of the requirements process are social and opportunistic, involving intensive and interpersonal interaction to construct understanding of the problem space. Use of interpretive field research to study the requirements process revealed the rationality of practice that may not be accessible to outsiders. Analysts act rationally and sensibly to explore intractable problem situations. Therefore, this research project provides an explanation for the observed informal and ad hoc nature of the requirements process. The activities of the early stages of the requirements process have a logic and rationality that can be observed and explained but not predicted. This suggests that increased formality in undertaking the requirements process is not the solution to its well-recognised problems but rather that increased support for the process as it is actually practised is needed. The integrated model presented in this paper forms the foundation for future research into how requirements are actually constructed in different contexts with different teams and consequently development of supports (tools, techniques and methods) based on understanding of the requirements process in practice.

The findings point to a crucial omission from research into the requirements process. It has long been acknowledged that the requirements process involves social factors (De Marco, 1978) but people have not been included as an integral part of the process. Much of the research has focussed on tools, modelling notations and specification languages rather than grappling with the essentially social nature of the requirements process (Davis, 1998). Brooks (1987:11), in his seminal article on the software crisis, argues that complexity is an inherent characteristic of software and notes that "*descriptions of a software entity that abstract away its complexity often abstract away its essence.*" This is apposite for studies of the requirements process. Descriptions and models of the requirements process that abstract away the unpredictable and messy human aspect have abstracted away its essence. Omitting people from models of the requirements process means that an inherent part of the process is ignored. As a result, formal or technical solutions have been offered for problems that include substantial social and cognitive components. Researchers "*continue to solve the simple (that is, technical) parts of hard problems*" (Davis, 1998:7). Inclusion of people in the integrated model of the requirements process is a step towards rectifying this omission. The integrated model provides an example of how to incorporate social as well as technical aspects in the requirements process.

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