A MULTIPLE PERSPECTIVE APPROACH TO INFORMATION SYSTEM QUALITY

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This thesis is dedicated

to

Theo and Bertie

Abstract

The motivation for this research is a concern with the high rate of information system failures reported in the academic literature and in practitioner publications. It is proposed that the adoption of the customer-centred ideals and methods of quality management in information system development will increase the likelihood of the delivery of successful information systems. The approach taken in the research is to work with the ideas of multiple perspectives - organizational effectiveness, work-life quality, and technical artefact quality - and multiple stakeholders.

The research approach is to use action research. The fieldwork comprises three phases. The first phase involved interviewing system developers and the second phase consisted of two case studies of implemented information systems. This preliminary analysis, together with a theoretical investigation of the foundations of quality, was used to inform the development of a quality approach to information system development. The information system development methodology (ISDM) is based upon Multiview, a multiple perspective approach to information system development, and the total quality management method used is quality function deployment. The resultant hybrid methodology is known as ISDM/Q.

The ISDM/Q is tested using action research on a live system development project concerned with the development of a wind tunnel control and data collection system. Extensive organizational analysis was conducted to place this software development within a wider organizational context, involving quality requirements workshops and quality planning. The outcomes of the research are assessed in terms of the learning recorded with respect to the framework of ideas, the methodology (ISDM/Q) and the domain in which the action research took place. The field work showed that there were benefits to using a quality metaphor in information system development but that this would require a significant change in the culture and style of information system development organizations. A practical contribution of the research is the development of quality function deployment for information system development.

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Preface

Having spent a number of years in the computing industry, working with a software vendor, as a freelance consultant, and as a system developer in the banking sector, it became apparent to the author that there is a considerable gap between the theory and the practice of information system development. However good the methods and the tools, the messiness and uncertainty of the organizations and the personalities of those involved seem to have conspired consistently against a rational and orderly information system development process. This thesis represents the author's attempt to understand and make sense of his experiences of IS development. The author's background and experiences are relevant to the way in which the research was approached and, especially given that action research was employed, to the way in which it unfolded.

The author's background

On graduating from Manchester University the author joined a U.S. software company, MSA, whose business was the development, marketing, and support of mainframe accounting packages, such as General Ledger, Accounts Payable, Manufacturing, and Logistics. In six years at MSA the author was involved in a number of activities, including software development, customer support, and sales support. During this time there were many changes: the organization grew dramatically; batch mainframe systems became online, and then real-time; and the micro-computer appeared and was used for entering and manipulating mainframe data. Latterly, client-server architectures and open systems were recognized by MSA as key technology issues.

A considerable amount of the author's time was spent in customer support where there were many (hundreds to low thousands) outstanding service requests (software problems reported by customers) for each software product. Although many of its customers were satisfied with the products and some were excellent reference sites, MSA did not have a particularly good reputation as a supplier of quality software. However, MSA was an effective sales and marketing organization and achieved considerable success in the marketplace. Through working in customer support it became clear that quality did not relate purely to conformance to specification, to the number of outstanding service requests, or to the absolute time taken to resolve a software problem. The resolution of a customer's problem in a satisfactory manner often resulted in a better relationship with that customer and increased satisfaction - a customer problem was an opportunity to demonstrate the effectiveness of the support operation. This experience demonstrated the importance of managing customer expectations. For example, if the software company promised to deliver a solution in three days and it took four days then the customer perceived the software company as having failed. If the solution was promised in five days and delivered in four days then the customer's expectations could be exceeded and a reputation for providing a reliable service would be strengthened. Of course, the level of performance had not changed insofar as it still took four days to develop the modification - the difference was that customer expectations had been more effectively managed.

On leaving MSA the author spent four years as a freelance consultant, helping organizations to implement MSA software products. This role covered many aspects of software implementation ranging from writing production JCL (job control language) to project management. One project for a high-street bank involved co-ordinating the efforts of about forty people directly and hundreds of application users indirectly through the user members of the project team. The project went live on time and despite a few teething problems was counted a "success" by the bank's management.

It is fair to say that the project was reasonably successful, but there were a number of the implementation problems could have been avoided; for example, a large number of temporary staff had to be employed to clear out suspense account entries in the General Ledger - these resulted from an ineffective procedure for setting up new account codes. The user and IT management felt that the project was a success, mainly because it went live as scheduled and was only a small percentage over budget - this was a good effort based on the bank's track record in system development. However, the understatement of human and organizational costs is a common feature of IT projects (Willcocks 1992) and this small budget overrun did not reflect the true cost of the project. The fact that it took three months and extra temporary clerical staff to iron out post-implementation problems could be hidden in user departments without too much trouble; the important thing for the IT and user management was that the project could be held up as a success. This experience lead the author to the feeling that success and failure depend to a remarkably large extent on one's position in the organization and the nature of one's stake in the project. No doubt some of the direct users of the system were less than delighted with the new system, but they were powerless to make their voices heard in the places that count. When analyzing success and failure it is second nature to ascribe cause and effect to events: the system went live on time because the project was well-managed, or it was late because the testing was not thorough enough. Latour comments succinctly on the politics of explanation, 'belief in causes and effect is always, in some sense, the admiration for a chain of command or the hatred of a mob looking for someone to stone' (Latour 1988, p.162).

A long association with the bank together with this "successful" implementation resulted in the offer of a job as an information system development manager. At that time the bank was attempting a major reorganization and centralization of financial reporting and the next two years were typified by intense political wrangling as the senior managers attempted to carve themselves out a chunk of the organization. It seemed that the personal ambitions of the managers played a large part in how the organization would be structured and influenced significant strategic decisions (Knights & Murray (1994) address this issue). These outcomes were legitimated in language that drew upon "business urgency", "customer service", "market pressures", and so on. But it was difficult to ignore the personal and organizational politics that seemed to bubble away continuously in the background, and if the user manager of a division wanted a software development project to fail, then, by and large, they could bring this outcome about; similarly, if they wanted it to succeed then to a large extent they could also bring about this outcome. Markus (1983) has described a similar situation in a case study of the implementation of an accounting system into a banking environment. Markus' account rang true for the author and reinforced the belief that technical competence is not enough to secure the successful use of information technology.

Following a structured method, such as SSADM (Structured Systems Analysis and Design Method) or Arthur Andersen's Method/1, will help developers in organizing and executing the technical activities of application development but methods can become an almost insignificant factor in the face of organizational and personal politics. However, the culture of large organizations is often such that social, personal, and political factors cannot be written down and cannot be discussed openly in formal gatherings such as steering committee meetings. This does not mean that they are not discussed, they are discussed constantly and at great length behind just about every (closed) door in every building.

This is the background that informs and motivates the author's research interest in the organizational context of IS development.

1

The research theme

Introduction

In this chapter the motivation for the research and its importance are presented and the research theme is articulated. The assumptions that underpin the research are declared, particularly with respect to information systems, quality, and information system quality. The structure of the thesis is outlined together with a brief synopsis of the constituent chapters.

1.1 The research issue

Despite attempts to make software development more rigorous, a considerable proportion of computer system development efforts results in products that do not provide user satisfaction. Lyytinen & Hirschheim (1987) conclude that 75% of all system development efforts were cancelled, or the completed systems never used. More specifically, Jayaratna (1990) provides an analysis of a US federal software budget of $6.2 million that shows: less than 2% of software products were used as delivered; 3% were used after change; 19% were abandoned or reworked; 29% were paid for but not delivered; and 47% were delivered but never used. Eason (1992) comments that the most common outcome is for technology to be used by a limited sector of the potential user population, with such use involving but a small part of the available functionality of the technology. Lyytinen (1988) comments that:

> ....information system problems are so widely spread and pervasive that one may speak of IS failures. Moreover case studies have vividly illuminated that the problems generated are many and no single feature can describe an IS failure entirely. (p. 61).

The seemingly high level of IS failures is the motivation for this research, being informed by both the IS literature and the author's personal experiences as an IS developer. Given that concern about IS failure is the motivation for the research it is appropriate to consider in more depth what might be the characteristics of "success" and "failure" in IS development. Lyytinen & Hirschheim (1987) identify three traditional types of IS failure: correspondence failure, process failure, and interaction failure. *Correspondence* failure reflects a predominantly management view and occurs when stated design objectives are not met; *process* failure occurs when the IS development process cannot produce a workable system, or when a system is produced but at a high level of budget or time overrun (Gladden 1982); *interaction* failure is indicated by low levels of use and poor user satisfaction (Bailey & Pearson 1983).

Lyytinen & Hirschheim (ibid.) identify a fourth type of failure, *expectation* failure, which subsumes the three traditional types of failure. Expectation failure is linked to a stakeholder (Mason & Mitroff 1981) view of information systems in which there are no general failures - any IS failure must pose a problem for someone or some group. Lyytinen & Hirschheim (ibid.) conclude that 'we need more studies on how various stakeholder groups are affected by IS development and use' (p. 297), that 'there is a lack of a comprehensive list of criteria for identifying relevant stakeholders' (p. 298), and that 'there is also a paucity of methods by which to determine and formulate their expectations adequately' (p. 298).

Undoubtedly there is a lot to be learnt from studying IS failures and through the development of an IS failure theory that avoids weaknesses such as one-dimensionality (one aspect of the IS defines a failure), a binary view of success and failure (an IS is either a success *or* a failure), neutral measurement (everybody wins or everybody loses), and a static state (once a failure, always a failure) (Lyytinen 1988). However, one can also approach failure from the positive aspect of identifying strategies in IS development that might contribute to IS success and one such approach is to adopt a quality metaphor. A fundamental aspect of quality management is the concept of customer satisfaction, which this author proposes is a potentially useful organizing principle for IS development, particularly if the aim is to lessen the incidence of expectation failure.

This research is therefore concerned with combining the ideas and methods of a quality metaphor with IS development. The proposition (*why* it is being done) of this research is:

The adoption of a quality approach to information systems development will contribute to the delivery of successful information systems

The approach (*how* it will be done) is to use action research. In Checkland's (1991) model of action research a framework of ideas, F, is declared and a methodology, M developed. The methodology (M) is tested in an area of application, A, and the framework and methodology (F, M) refined. Following the researcher's exit from the area of application (A) there must be reflection on the learning that has come about with respect to F, M, and A. The success of this research should be assessed in part on the quality of this learning experience. In particular the learning outcomes should be expected to provide insight into the following issues:

- what are the practical and theoretical implications of combining IS development and quality management?
- what are the implications of quality management for IS success?
- what are the implications of IS development for quality management?
- what can be learnt about the process and nature of IS development?

The planned contribution of the research is therefore a deeper understanding of quality and IS development together with the development of practical methods for the achievement of IS quality.

1.2 Assumptions concerning information systems

There are a number of underlying assumptions that need to be declared at the outset in order that the research theme outlined above can be placed in the context of the IS research tradition. Davis (1974) has defined an information system to be:

> an integrated man/machine system for providing information to support the operations, management and decision making functions in an organization. The system uses computer hardware, software, manual procedures, management and decision models and a data base.

The above definition places an IS between the activity that organizational members undertake and the technology they use to support those activities. Ives et al. (1980) have provided a similar definition:

> a computer-based organizational information system which provides information support for management activities and functions

Three major concerns of an IS can be identified from the above definitions, namely technological, managerial, and organizational. Following Lyytinen (1992), this author takes management support to include all organizational participants, not just those who are designated "manager". The domain of IS research has been defined by the UK Academy for Information Systems (1996):

> The study of information systems and their development is a multi-disciplinary subject and addresses the range of strategic, managerial and operational activities involved in gathering, processing, storing, distributing and use of information, and its associated technologies, in society and organisations.

This broad definition of the IS field incorporates the themes of organizations, management, and technology while providing a categorization of types of organizational activity. Although we tend to assume that information systems will use computer-based technical artefacts, they need not necessarily do so. Technology includes not only computers but also things such as diagrams, methods, techniques, and procedure manuals. An information system might well employ 'associated technologies', such as filing cabinets and card indexes, but does not necessarily have to employ computer-based technology. However, in the current age computer-based technologies are a ubiquitous aspect of information systems and thus will form the focus for attention in this research.

The terms "information" and "system" are now considered separately and then recombined to give the author's view of an information system.

1.2.1 Information

Checkland & Scholes (1990) define information as data to which meaning has been attributed (p. 55). Meaning attribution is an essentially human activity and thus Checkland would argue that computer-based technical artefacts can hold data but cannot hold information. Data can be interpreted in different ways by different people, resulting in different and multiple sets of information (Kent 1978; Wilson 1991). If one accepts Checkland's definition of information then the role of the information system is to capture, process, and store data, to give human actors access to stored data, and to support those actors in interpreting and transforming data into information that can be used to support organisational activity. Computer-based technical artefacts are but one source of data, albeit an increasingly important one, within an information system that incorporates formal and informal mechanisms for the creation of information.

A counter view is to equate information systems with computer-based technical artefacts and therefore information system development with the construction of databases and software applications. In such a world computer-based technical artefacts are stores of information - information can be stored because the meaning is retained in the technical artefact. Meaning, once attributed, can be stored with the data. However, it is arguable whether meaning can be captured in this way. Boland (1987) argues that by assuming that a concept such as information has a real world existence we first *reify* it; by seeing it as embodied in computer systems we *objectify* it - in this way information becomes a real world entity that can be stored in a computer-based technical artefact. In Boland's opinion the difficult issue of how meaning is negotiated has been deferred: 'information is not a commodity - it is a skilled human accomplishment' (Boland 1987, p. 370).

In the above section two views of information have been identified which in their extremes state that (a) information is subjective and data means whatever somebody says it means, and (b) information is objective and is a real-world attribute of data (Shannon & Weaver 1964). Goguen (1992, 1994) has proposed the idea of *wet* and *dry* information. Dry information can be understood in a variety of contexts while wet information is more situated and needs to be understood in context. Goguen (1992) points out that a more reasonable assumption is of a continuum of wet and dry and that one should not expect to find examples of the extremes, that is, entirely dry data that can be understood by anyone at any time, and data so wet that it can only be understood when and where it is produced (p.173).

1.2.2 Systems

The soft systems approach as described by Checkland (1981) draws upon the tradition of hard systems engineering and General Systems Theory (Bertalanffy 1950, 1968; Boulding 1956) and the Singerian enquiring systems proposed by Churchman (1968, 1971, 1979). Checkland argues that with respect to human activity a hard systems approach is not appropriate and he proposes that systems ideas be used as formal and rigorous way of organizing thought about real-world problem situations - the assumption in soft systems thinking is that although the methodology can be systemic the perceived world is problematic (Checkland 1981; Checkland & Scholes 1990). This is in contrast to a hard systems approach, in which the perceived world is assumed to be systemic, i.e., systems are taken to have a real world existence, while the methodology should be systematic. The soft systems tradition has undoubtedly been a major contributor to the development of the information systems discipline and at the time of writing is being adopted as part of SSADM (Structured Systems Analysis & Design Method) Version 4, which is the most widely-used structured development method in the UK (Goodland & Slater 1995).

In soft systems thinking the term "system" has a precise meaning. Unfortunately, that meaning is not reflected in everyday language where the word "system" is appended to many areas of human activity, such as education system and health system. However, this does not mean that these are real-world systems. In soft systems terms these are problem situations for which systemic models can be created to serve as a basis for debate. To avoid confusion between the world of ideas and the perceived world a soft systems thinker will often refer to holon rather than system - holonic models of human activity can be created to help us think about the real world, which we imprecisely consider to contain "systems". This imprecision results in the status of information systems being indeterminate.

1.2.3 Information systems and technical artefacts

If one assumes that firstly, information is an objective characteristic of data, and secondly, that systems have a real-world existence, then a computer-based technical artefact can be truly said to be an "information system" - it holds information and is systemic. Conversely, if one assumes that information is the result of meaning attribution and that the perceived world is problematic then one should talk of data processors - computer-based technical artefacts hold data. By combining the different notions of information and systems four different views of computer-based technical artefacts are generated (figure 1.1). The four quadrants represent outcomes of dualistic thinking: hard versus soft systems and objective versus subjective information.

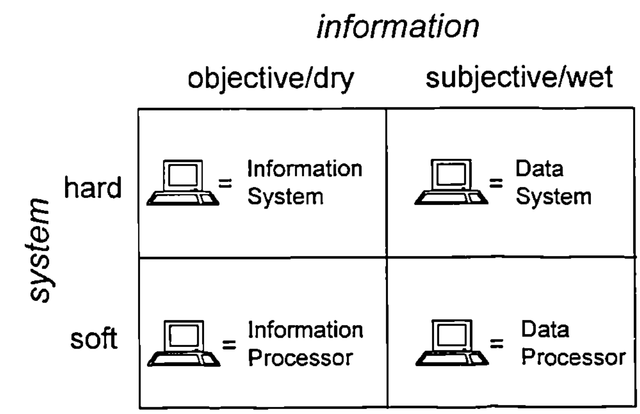


Figure 1.1: different views of the status of computer-based technical artefacts

An on-going theme of this thesis is to detect and explore binary oppositions and to introduce symmetry where appropriate. Accordingly, figure 1.2 represents the author's view of information systems as a mediator between organizational context and technical artefacts. Thus an information system is neither wholly a real-world entity nor purely a conceptual device for organizing our thoughts about the world. The notion of an "information system" is both a (conceptual) way of separating the (inseparable) issues of organization and technical artefacts as well as a (practical) way of bringing them together in a network of alliances between human and non-human actors.

Having given consideration to what might be meant by the terms "information", "system", and "information systems", in the next section the idea of quality is introduced.

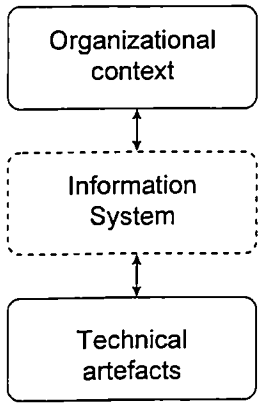


Figure 1.2: organizational context and technical artefacts

1.3 Assumptions concerning quality

A widely used definition of quality has been supplied by the International Standards Organization (ISO8042 1986):

> The totality of features and characteristics of a product or service that bear on its ability to satisfy specified or implied needs.

This view of quality has come to dominate the quality movement. The prevailing orthodoxy of quality is represented by Total Quality Management (TQM) (Deming 1982; Oakland 1989; Thorn 1988), which places a great emphasis on the customer/supplier relationship, regardless of whether that relationship involves internal departments or other (external) organisations. In TQM the need for communication and control is stressed, with three types of communication being identified: down-the-line (hierarchical, process-based); lateral (cross-department, often project-based); and consultation, for example, encouraging managers to listen to their staff. Control is achieved through the setting of clear targets and the monitoring of performance. Some cultural aspects are addressed in TQM by encouraging employees to take ownership of the quality culture, thereby promoting a sense of belonging and co-operation.

The importance of the contextual aspect of quality can be seen in figure 1.3, Deming's 'three corners of quality' (1982, p. 176). The three corners are product, service, and use. The use corner is concerned with the way the customer uses the product and makes it clear that quality is not something that resides wholly in the product - it is a judgement that arises from the interaction of a customer with a product and is affected by the level of service.

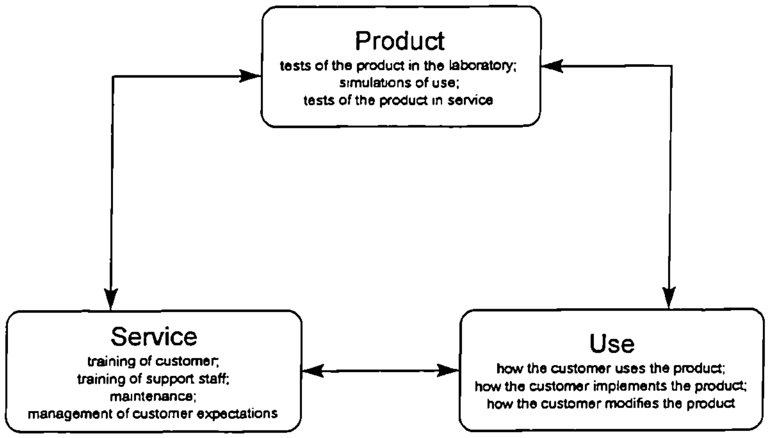


Figure 1.3: three corners of quality (adapted from Deming 1982)

It was noted above that concepts such as information are subject to reification and objectification. Similarly, the concept quality is easily reified, that is, quality is a taken for granted real-world phenomenon, and then objectified, following which quality is an attribute of a product. This objectification is the Rolls-Royce effect, whereby it is accepted that the Rolls-Royce *is* a quality motor car and the Rolls-Royce comes to stand as a symbol of quality for motor cars. The objectification of quality can be helped along by the use of metrics. By assigning objective measures to products it is all to easy to mistake the map for the territory and for the metrics to come to define what constitutes quality. For example, ten coats of paint *is* a high quality bodywork finish. In the next section it is argued that the software development community has failed to embrace the idea that quality is a judgement made by customers.

1.4 Quality in information systems development

Wood-Harper (1989) bases his definition of an information system development methodology on Checkland (1983a) and Lyytinen (1986):

> a coherent collection of concepts, beliefs, values and principles supported by resources to help a problem-solving group to perceive, generate, assess and carry out in a non-random way changes to the information situation (p. 16).

The terms "methodology" and "method" tend to be used interchangeably, although they can be distinguished insofar as a method is a concrete procedure for getting something done while a methodology is a higher-level construct which provides a rationale for choosing between different methods. In this sense, an IS methodology would provide some criteria for choosing between different development methods (Oliga 1988).

Fitzgerald (1996) identifies a number of arguments for formalized IS development methodologies, including: subdivision of work, facilitation of project management, a framework for techniques, specialization of labour, knowledge acquisition and systematization, and standardization of the development process (interchangeability among developers and increased productivity and quality). Fitzgerald (ibid.) also recognizes a number of pressures for increased formalism: the desirability of certification from bodies such as ISO and the Software Engineering Institute, and a general feeling in the IS literature that better methods will solve the problems of IS and IS development (Jenkins et al. 1984).

The scope of IS development methodologies varies with some covering organizational aspects but not the details of technical artefact design and construction, while other methodologies focus primarily on the design and development of software. The range of IS development approaches, from organizational analysis through to software engineering, is represented on the *x*-axis of figure 1.4. Similarly, one can see different approaches to quality management that range from supplier-focused to customer-focused approaches. In its narrow, supplier-focused form quality management might be reduced to final product inspection, while in its broader (total) form quality management is an institutionalized way of life in which the needs of the customer drive all aspects of an organization's activities. This range of approaches to quality is depicted on the *y*-axis of figure 1.4.

This author argues that software quality is characterized by a supplier/technology focus and that although some of the techniques of quality management are being adopted, such as process capability improvement, the broad forms of quality management have yet to be embraced with any real enthusiasm

(Vidgen et al. 1993). Moving away from technology toward the organizational end of the spectrum one finds that the ideas of TQM are becoming an accepted part of management practice.

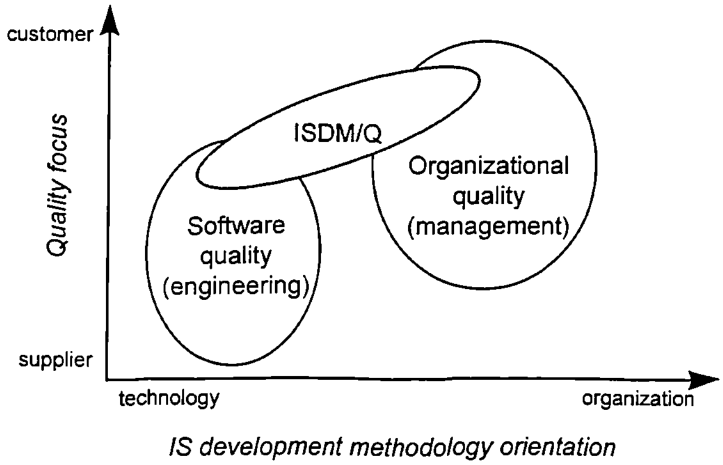


Figure 1.4: a quality approach to IS development (ISDM/Q)

This research is illustrated by the area labelled ISDM/Q which represents a combination of an IS development methodology (the "ISDM") and a broad notion of quality that emphasizes the customer rather than the supplier (the "Q"). The positioning of the ISDM/Q in figure 1.4 also reflects a concern with bridging the worlds of organizational activity and software engineering such that the technical artefacts have 'fitness for use' (Juran 1979).

There is a tradition in software engineering of addressing correspondence failure (requirements engineering), process failure (capability maturity models), and interaction failure (user information satisfaction) and all of these approaches have a close affinity with the ideas of quality management. However, there is little evidence that the problems of expectation failure have been addressed sufficiently in IS development, which needs a recognition of multiple stakeholders and a broad, customer satisfaction based view of quality. One aim of chapter 2 is to substantiate the author's claim that there is an identifiable gap in the IS and quality literature that would be addressed in a small part by this research.

1.5 Thesis structure

The structure of the thesis is given by figure 1.5, which shows the chapters and the major inter-dependencies between chapters.

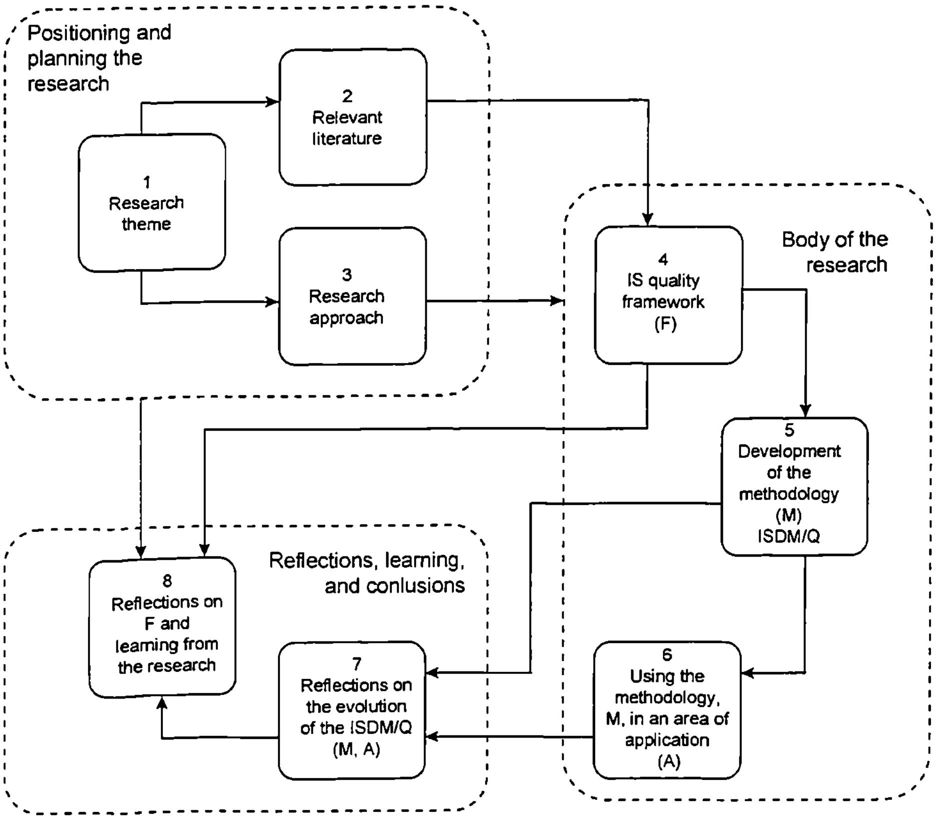


Figure 1.5: structure of the thesis

1.5.1 Summary of chapter contents

The contents of the chapters are as follows:

Chapter 1: The research theme

The motivation for undertaking the research is declared and the research theme outlined. Assumptions concerning information systems, quality, and information systems development are given to place the research theme in the context of the IS tradition. It is proposed that there is a need for research at the intersection of IS development and quality management.

Chapter 2: Review of relevant literature

Relevant literature in quality, management, human resources, information systems development, and software engineering is reviewed in the context of the research theme. The aims of the literature review are to substantiate the claim that there is a need for work to be carried out at the intersection of IS development and quality management, and to place this research in the context of prior research.

Chapter 3: Choice of a research approach

Different traditions in research approaches are described and a framework for positioning IS research is proposed and used to guide the selection of a specific research approach for this thesis. The chosen approach is to combine case study with action research.

Chapter 4: A multiple perspective framework for IS quality

Different definitions of quality and assumptions about the constitution of quality are investigated in depth, leading to an IS quality framework (F) which is used to inform the development of a quality approach to IS development (ISDM/Q).

Chapter 5: Development of the methodology - ISDM/Q

In developing a quality approach to IS development interviews of system developers and case studies of software users are conducted in order to understand what factors might be important in defining and improving IS quality. The IS quality framework of chapter 4 and the data collected in the first phases of the fieldwork are used to develop a provisional form of the ISDM/Q.

Chapter 6: Applying the ISDM/Q

The ISDM/Q is applied through action research in an area of application (A). In this chapter detailed descriptions of how the techniques were applied together with the resulting outputs are provided.

Chapter 7: Reflections on the evolution of the ISDM/Q

The provisional form of the ISDM/Q presented in chapter 5 evolved through the experiences of the action research described in chapter 6. Reflections on the use and development of the ISDM/Q in the area of application (M, A) are given (first order learning), including lessons learnt from the fieldwork, culminating in a description of the evolved form of the ISDM/Q.

Chapter 8: Learning from the research and conclusions

Reflections on the framework of ideas (F) are made (second order learning) and the results evaluated in the context of the research theme outlined in chapter 1. The contribution of the research to theory and practice of IS development and quality management is evaluated critically and areas for future research are identified.

Chapter summary

The motivation for the research and its importance have been declared and the research theme articulated. The basic assumptions adopted in this research concerning information, systems, information systems, quality, and information system quality have been introduced. The research has been positioned at the intersection of IS development methodologies and customer-focused quality management - a space labelled ISDM/Q. In the next chapter a review of the literature is conducted in order to place this research in the context of prior work and to justify the claim that there is a potential contribution to be made through conducting this research.

2

Review of relevant literature

Introduction

In chapter 1 the research theme was presented and assumptions concerning information systems (IS) and quality were declared. Chapter 1 concluded that there was a need for research to be conducted at the intersection of IS development methodologies and customer-focused quality management, this domain being labelled ISDM/Q to represent the orthogonal interests of IS development and quality. The aims of chapter 2 are firstly to place the research described in this thesis within the context of previous research into IS development and TQM, and secondly to substantiate the claim in chapter 1 that this is a research area that has not previously been investigated in sufficient depth, i.e., that the development and testing of an ISDM/Q has the potential to contribute to IS research and IS practice.

The structure of the chapter is shown in figure 2.1. The background to the quality movement is provided in the first section and is followed in the second section by a review of quality management methods. In the third section a taxonomy of IS development approaches is described, with a particular emphasis on IS requirements analysis in order to maintain a customer-centred focus. In the fourth section literature concerned with the application of TQM techniques to software and IS development is reviewed.

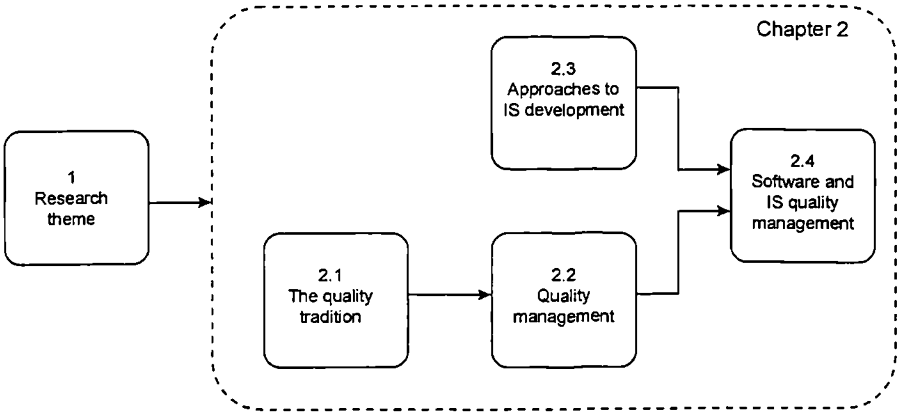


Figure 2.1: structure of chapter 2

2.1 The quality tradition

2.1.1 Origins of the quality movement

The roots of Total Quality Management (TQM) can be found in the 1930s with W.A. Shewart's (1931) development of statistical control processes for the sampling of variations in output. According to Flood (1993) another major influence on quality techniques was the development of operational research techniques, which flourished in the UK during the Second World War, but tailed off in the post-war years. In Japan, however, there was a national drive to expand the economy through growth of the manufacturing base. In 1950 Japanese products had a reputation for shoddy quality, but, according to Deming (1982), by 1954 had improved quality and dependability to such an extent that they 'captured markets the world over' (p. 486). W. Edwards Deming was one of the Americans who visited Japan following the Second World War to lecture and advise on quality management to Japanese management, training over four hundred engineers in the quality control methods of Shewart during the summer of 1950. Juran visited Japan in 1954 and promoted a stronger management perspective to quality improvement. The quality revolution in Japan in the 1950s was facilitated in a large part by the Union of Japanese Science and Engineering (JUSE), who had strong backing from Japanese industry and government.

In the 1970's the move from quality control to a broader view of quality management began to be established. Deming (1982) was concerned that a reliance on inspection leads to fire-fighting and that it takes responsibility for quality away from the people best-placed to ensure quality - those making the product or delivering the service - by placing it in the hands of proliferating quality control departments. Deming advocated fault *avoidance* rather than fault *recognition*, an approach reflected in Ishikawa's (1985) use of quality circles in Japan in the 1960s.

The theme of avoidance versus recognition was developed further in the influential book 'Quality is Free' in which Crosby (1979) argued that quality must be built in to a product rather than relying on post-production inspection and fault rectification. From this rhetoric the slogan 'do it right first time' arose. Feigenbaum (1983) recognizes the danger of tackling quality management through a piecemeal approach and argues for an organization-wide approach to quality and the establishment of a quality culture. The need for quality improvement in the West was also bolstered in the 1970s by a comparison of Japanese success, which was accounted for by the development of a quality culture, with Western decline (Tuckman 1995). By the end of the 1980s Total Quality Management (TQM) was the dominant theme of quality improvement programmes.

2.1.2 Total quality management (TQM)

From a historical perspective, Tuckman (1995) has identified four, overlapping, phases of TQM (table 2.1). In the first phase there was a recognition of the importance of quality and the formation of quality circles (Ishikawa 1985). Today quality circles are not in general use and are perceived as having done little to increase employee involvement or to improve operational effectiveness; however, they did clear the way for a broader view of quality and TQM (Hill 1995). In the second phase of TQM development organizations realized the need to manage suppliers and materials, which lead to an interest in techniques and methods such as just-in-time inventory and quality assurance standards, such as the ISO9000 series.

The third phase in the development of TQM was for it to be embraced by organizations not involved in manufacturing and for the idea of a customer-supplier chain to apply intra- as well as inter-organizationally. In the fourth phase the customer-supplier metaphor has been adopted in areas where previously it would have been alien, such as health, education, and public welfare.

Phase	characteristics
late 1970s to early 1980s	experimentation with quality circles; prevalent in organizations affected by competition from Japan (e.g., electronics and motor car industries)
1980s	major organizations become concerned with control of suppliers and sub-contractors
mid-1980s onwards	a focus on customers, both inter- and intra-organizational
late 1980s onwards	the notion of customer service adopted in areas which previously had not recognized the existence of customers (e.g., the National Health Service)

Table 2.1: four phases of TQM (adapted from Tuckman (1995), p. 67)

The disparate theoretical foundations of TQM can be found in the work of Deming (1982), Juran (1988) and Ishikawa (1985). As the name suggests, TQM is concerned with the total activities an organization undertakes and therefore involves all employees in a continual process of improvement (also known as "Kaizen"). This total participation is coupled with a customer-focus to organizational activity, which provides a benchmark for the effectiveness of business improvement: the test of the market-place (which can be external or internal to an organization). A features of TQM is cross-functional management with horizontal organization that crosses the vertical, hierarchical structure. There is also a recognition of the need for management involvement, that workers alone cannot make the changes needed if quality improvement is to be achieved. The use of statistical measures is encouraged for identifying non-conformances and in assessing process performance - 'management by fact' (Garvin 1991). TQM also drives and relies upon cultural change whereby quality ideals and continuous improvement are internalized.

2.1.3 Implementing TQM

The implementation of TQM is a long-term and painful process that is typified by a high failure rate; Kearney (1992) reports on survey results that indicate 80% of TQM initiatives fail to deliver quantifiable or qualitative improvements. Flood (1993) has summarized some of the difficulties in implementing a TQM programme:

- the devolution of power and responsibility required by TQM is difficult for managers to accept;

- the idea of internal customers can lead to a reinforcement of bureaucracy that has no connection with external customers;
- managers who are expected to adopt a hard (measurable, statistical, mathematical) approach to TQM find themselves in difficulty in situations where quantitative assessments are not suitable. Where soft and qualitative assessments are more suitable but not available the TQM program lacks relevance and loses direction;
- TQM is founded on the notion of continuous improvement; if a competitor is making progress in a discontinuous fashion then the TQM organization can be left behind;
- TQM has no unified philosophy.

In the rather more prosaic language of the practitioner, Goodman (1995) proposes that TQM initiatives fail due to: a lack of management commitment; staff inexperience; ineffective implementation; an absence of change management; and size and complexity.

2.1.4 Critical views of TQM

Webb (1995) has identified two strands of academic critique. The first is pragmatic and broadly optimistic, the second is more pessimistic, seeing the application of TQM/JIT principles as leading to greater management control, surveillance, and the intensification of work. It has also been pointed out that the logic of markets can result in TQM being used to legitimate the actions of senior management (Wilkinson et al. 1991; Wilkinson 1992). Webb (ibid.) concludes that:

> At worst, particularly in a recession, the ideology of TQM reduces honesty, integrity, authenticity 'and all those good, nice words' to marketable commodities which have a price just like any other goods; it reduces workplace relations to the 'imperatives of the market' and becomes an excuse for managerialist, and immoral, expediency. (p. 125).

The current author subscribes to the *broadly* optimistic school of criticism of TQM, but wishes to maintain a sensitivity to the potential misuse of TQM that would contribute to inhibition and repression rather than empowerment and liberation. This is a theme that will be returned to in chapter 4, when critical aspects of IS development and quality are investigated.

2.1.5 Summary

In summary, the author believes that TQM is problematical from both theoretical and practical perspectives. Common themes and ideas are identifiable in the TQM ideology, but a cohesive set of ideas appears to be absent. In practical terms TQM is difficult to achieve since it requires that the organization develop a quality culture, that individuals take greater responsibility for their actions, and that operational procedures be rigorously defined and monitored. For a TQM implementation to be successful it must address all of these issues and do so within a context of striving for continuous improvement.

Based on this review of the history and ideas of TQM it is the author's opinion that for IS quality to be achieved there will need to be an appropriate organizational culture and internalization of quality values by system developers. The indications are that this is difficult to achieve. The author also wishes to maintain an awareness of the potential for TQM to be motivated and driven by the 'imperative of the market' to the exclusion of all other concerns.

In the next section methods and techniques for the management of quality are reviewed.

2.2 Quality management

The International Standards Organization (ISO) defines a quality management system (QMS) as:

> The organizational structure, responsibilities, procedures, processes and resources for implementing quality management (ISO8042 1986)

A principal component of any QMS is quality assurance (QA), which for many organizations has come to epitomise quality and quality management.

2.2.1 Quality assurance (QA) standards

The ISO9000 series addresses quality assurance (QA) and although it is a generic standard, there is a bias toward traditional manufacturing industries (table 2.2). ISO9001 is applicable in situations in which there is a substantial element of design. In situations in which the design is predefined then the focus is on production (ISO9002). Where there is little or no production then ISO9003 is applicable.

Standard	description
ISO9000	a guide to selecting the appropriate standard for QA
ISO9001	quality assurance of design, development, production, installation, and servicing
ISO9002	applicable to production and installation only
ISO9003	applicable to final inspection and test only
ISO9004	guidance in establishing QA such that it meets the ISO9001, ISO9002 and ISO9003 standards

Table 2.2: ISO Quality Assurance standards

Accreditation under ISO9000 is of three types: first party (self-assessment), second party (external assessment by a customer), and third party assessment (external monitoring by an independent standards body). Accreditation by a recognized third party is the highest level of accreditation and involves a detailed audit of procedures and documentation, with re-inspection being required on a periodic basis if an organization is to retain its accreditation. QA is defined in the ISO9000 documentation as:

> all those planned and systematic actions necessary to provide adequate confidence that an entity will fulfil requirements for quality

Given the ISO definition of quality, which refers to 'stated and implied needs', it is reasonable to assume that the ISO definition of QA is concerned with quality requirements in a fairly broad sense. The US based IEEE/ANSI definition of QA is in the same vein as ISO, but takes a more narrow perspective:

> a planned and systematic pattern of all activities to provide adequate confidence that the item or product conforms to established technical requirements

The Japanese Industrial Standards take the widest view of QA by defining it as

> a manufacturer's systematic activities intended to ensure that quality fully meets consumer needs

In the narrowest of senses QA is concerned with the production of consistent products that conform to specification. Whether or not the specification reflects customer demands is not an issue directly for QA - poor quality products may be produced but they are produced consistently and they are within tolerances defined in the specification. In such situations QA can become nothing more than a bureaucratic overhead (Braa & Ogrim 1994). The wider view of QA places manufacturing activity within the scope of the requirement that the products meet consumer needs.

2.2.2 Quality tools

This author takes the wider view of QA (as defined in the Japanese industrial standards) and is therefore interested in how one might be assured that the product will meet consumer needs. In order to develop an ISDM/Q the author requires methods and techniques in the provinces of both the "ISDM" and the "Q" domains. Unfortunately, there is no all-encompassing quality *method* available for TQM. The absence of defined methods may be due in part to the lack of agreement concerning a definition of TQM and the lack of a unifying theory. It is difficult to identify a definitive set of TQM techniques, but it is possible to find some common quality tools that typify TQM in the way that data flow diagramming and data modelling typify structured systems development. These TQM tools and techniques are now described.

2.2.2.1 Statistical process control & metrics

Statistical process control (SPC) is a long-established method of quality management. A process that is in statistical control is stable; a process that is not in control is unpredictable and results in inconsistent performance. The ethos of SPC is to get the process under control, then to analyse it, and ultimately to improve its capability. Zultner comments:

> It is essential for software organizations to collect, properly interpret, and improve via metrics. It is necessary, but not sufficient, for key software development processes to be in a state of statistical control. That only means they are predictable, and improvable. It does not necessarily mean we can satisfy the customer with them. (Zultner 1993, p. 80).

It has already been noted that measurement is a fundamental aspect of TQM, reflected in the adage: that which can be measured can be controlled; that which can be controlled can be managed; and that which can be managed can be improved. Flood (1995), who adopts a systems approach to quality, recognizes the importance of measurement but has reservations about the rationalist basis for deciding *what* to measure:

> Measurement is crucial in problem solving. Measurement specifications are the basic parameters by which an intervention is guided. The choice of specification is therefore a crucial one. The tendency is to go for specifications that have obvious quantitative measures such as durability, reliability, accuracy and/or speed. These mainly relate to processes........ these measures only cover the more technical elements of organizational processes..... They do not measure less tangible aspects of organization, for example assurance and empathy, the kinds of issue that are at the forefront of events whenever people are involved. (Flood 1995, p. 67).

Statistical control, grounded in quantitative metrics, is undoubtedly an important building block in quality management. However, in this author's opinion it is important firstly that statistical process control and measurement be placed in the softer context of how the decision concerning what is to be measured is made, and secondly it should be remembered that quantitative metrics are of little interest in themselves - they are surrogates for some less tangible quality that is of interest to the customer and supplier.

2.2.2.2 Seven tools of quality control

Ishikawa (1985) proposed a quality toolset that could be used across functions and at all levels in an organization. The seven tools are:

- *pareto charts*: useful for identifying the important types of errors that account for the greatest number of errors;
- *graphs*: display data and show trends - pie charts, bar charts, area graphs, etc.;
- *check sheets*: used to collect data in standard formats. This typically involves counting occurrences of events related to processes or products (see Oakland (1989) for examples of check sheets and resulting frequency distributions);
- *histograms*: helpful in understanding the variability of a process or product;
- *scatter plots*: used to show the relationship between two sets of data, usually with a regression line (e.g., Oakland (1989) shows a plot of product impurity against distillation temperature);
- *cause and effect diagrams*: also known as a "fishbone" diagram and is a useful aid to identifying causes of problems;

- *control charts*: errors are plotted and displayed with control limits, providing visual presentation of where and when a process is out of statistical control.

These seven quality tools are grounded in manufacturing and conformance to specification and as such represent the narrow view of QA. A broader view of QA is reflected in the seven management and planning tools.

2.2.2.3 Seven management and planning tools

Bossert (1991) describes seven management tools which were developed for application in areas outside of the traditional manufacturing base in which the seven quality control tools were developed. The seven tools are:

- *affinity diagrams*: used to structure customer needs and usually produced by the KJ method, a cognitive mapping approach in which a hierarchy of customer requirements is produced;
- *interrelationship digraphs*: these diagrams show relationships in a network form and are used to refine the issues surfaced as a result of the use of affinity diagrams. There are similarities with the mind maps promoted by Buzan (1993);
- *hierarchy diagram*: the affinity diagram and interrelationship digraph force issues to the surface (problem investigation); the hierarchy diagram is used to describe the methods by which a goal will be achieved (solution investigation);
- *matrix diagram*: matrices are used to show the connections between characteristics, functions, and tasks;
- *matrix data analysis*: sophisticated statistical analysis of multivariate data, including cluster analysis, factor analysis, and multiple regression;
- *process decision program chart*: a hierarchical diagram taken from reliability engineering and used for failure effect analysis;
- *arrow diagrams*: also known as a precedence diagram, this is an application of PERT, a well-established project management technique. It is useful for sequencing tasks and representing dependencies between tasks.

The management and planning tools are directed more toward quality requirements capture and address a customer/product view of quality whereas the seven quality control techniques are concerned more with a supplier/process view of quality. A number of the management and planning techniques have been combined into a systematic and sophisticated method of quality management known as quality function deployment.

2.2.3 Quality Function Deployment (QFD)

QFD is a translation of Japanese symbols and, as with many attempts to Westernize Japanese ideas, something is lost in the translation. QFD can be seen in two forms: the narrow definition of QFD is concerned with qualities deployment, the wider form with qualities *and* functions deployment. A broad definition of QFD is:

> A structured and disciplined process that provides a means to identify and carry the voice of the customer through each stage of product and or service development and implementation (Slabey 1990).

QFD addresses the "voice of the customer". Based upon a distinction of "what" and "how", a series of matrices are used to *deploy* customer *quality* requirements through design requirements, product *functions*, part characteristics, and manufacturing operations into production requirements (Hauser & Clausing 1988; King 1989). The narrow view of QFD focuses on demanded qualities and quality characteristics, but to get the full benefit of QFD it is necessary to take an end-to-end view of product design and manufacture.

A number of benefits have been claimed for QFD. A major benefit is that emphasis is placed on earlier stages of the development cycle, where changes are made at the 'high leverage end of the quality lever' (Slabey 1990). This has been recognized in software development where it has been asserted that errors in the specification of requirements have typically cost a hundred to a thousand times as much as those made during implementation (Boehm 1981). Other benefits claimed are: less time in development, fewer start-up problems, lower start-up costs, fewer field problems, satisfied customers, and organizational learning/knowledge transfer (Slabey 1990).

The primary venue for the discussion and development of QFD is the Symposium on Quality Function Deployment, which is held annually at Novi, Michigan. The terminology and provenance of QFD reflect a background in manufacturing, particularly the automotive (Wadke & Palumbo 1992; Fernandez et al. 1994) and aerospace (Lecuyer 1992; Bergman 1994) industries. However, the use of QFD is diversifying and includes healthcare (Gibson 1994; Erlich & Kratochwill 1994), human resource management (Harper et al. 1994), curriculum development (Richter & Lyman 1994), and, of course, software development (Newton & McDonald 1994; ElBoushi et al. 1994).

2.2.4 Service quality

A service view of quality is concerned with a customer's perception of the service provided by the supplying organization (Parasuraman et al. 1985; Zeithaml et al. 1988; Zeithaml et al. 1990). Services can be seen to differ from products in three ways: firstly, service is intangible (the product is a performance); secondly, services are heterogeneous (they vary from supplier to supplier, customer to customer); and thirdly, many services are inseparable (quality of service occurs during service delivery). Service quality, as perceived by customers, can be defined as the extent of discrepancy between customers' expectations or desires and their perceptions. Some of the key factors in forming customer expectations are: word-of-mouth communications; personal needs; past experience; and, external communications (Zeithaml et al. 1988). Attributes of the service organization that affect customers' perceptions of service quality include: reliability, responsiveness, assurance, empathy, and appearance. Gaps in service quality that explain the discrepancy have also been proposed: not knowing what customers expect; the wrong service quality standards; the actual service does not meet the service specification; and, promises of service do not match the service delivered (expectations have been raised too high).

2.2.5 Business process redesign

In recent years TQM has been challenged by business process redesign (BPR) in the management fashion stakes and the author believes that a relevant aspect of this research is to attempt a reconciliation between the two approaches. In this section the ideas underlying BPR are presented.

A business process has been defined as:

> A process is a set of linked activities that takes an input and transforms it to create an output. It should add value to the input and create an output that is more useful and effective to the recipient (Johansson et al. 1993)

and,

> A collection of activities that takes one or more kinds of input and creates an output that is of value to the customer (Hammer & Champy 1993)

There is a common thread to these definitions of process, namely the idea of inputs being transformed to outputs for some purpose. Business process redesign (BPR) is founded on this process perspective and has been defined as:

> The fundamental rethinking and redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed (Hammer 1990)

and,

> BPR is the means by which an organization can achieve radical change in performance as measured in cost, cycle time, service, and quality, by the application of a variety of tools and techniques that focus on the business as a set of related customer-oriented core business processes rather than a set of organizational functions (Johansson et al. 1993)

The redesign of processes is conducted within the context of customers and customer quality requirements rather than for the convenience of the supplier. Clearly there are some close parallels with a customer-focused approach to quality management. From a reading of these popular BPR texts a number of BPR tenets can be identified. The central notion of 'an initiative which combines process orientation with an edict for radical change' (Kawalek 1993) may be expanded to include:

- radical change and assumption challenging;
- process and goal orientation;
- organizational re-structuring;
- the exploitation of enabling technologies, particularly information technology.

To qualify for categorisation as BPR, change must be radical. For change to be radical rather than incremental requires that basic assumptions be challenged to avoid being trapped by the way things are currently done. Change becomes an essential part of 'normal' life rather than something to be avoided, a catalyst for getting ahead of the competition and staying there. The need for goal-oriented processes is recognized; each process is seen as part of a chain, and each process must add value to the products it handles with the ultimate aim of providing an end-product that the customer wants. Processes should not be viewed as tasks but as activities that achieve a goal, and may involve transcending intra-organizational and inter-organizational boundaries. Radically re-visioned processes drive the shape of the organization, rather than current structures (such as departments). The conception of organization in BPR is post-industrial and post-modern in the 'epoch' sense suggested by (Hassard 1993 drawing upon Clegg 1990), which is characterised by a craft-orientation, a multi-skilled workforce, and flexible manufacturing. Possible changes to the organization are not limited to internal re-orderings; whole activities can be out-sourced and parts of processes transferred to customers and suppliers. Links can be forged with other organizations even when they are competitors. This leads to a view of the organization as a fluid mix of interests rather than a fixed entity with an objective existence.

In common with TQM there is no unifying theory of BPR and such methodology as exists is pragmatic and ad-hoc in nature, such as Guha et al. (1993) who present their 'comprehensive methodology' in the form of a SSM conceptual model, although without acknowledgement. Wastell et al. (1994) have proposed a methodology for BPR, PADM (process analysis and design methodology), which has emerged from practical experience of using techniques such as role activity diagramming (Ould 1995). Wastell et al. (1994) point to the importance of taking a sociotechnical perspective on BPR, an argument also made by Mumford (1995).

As with TQM, BPR has also come in for criticism. Grint et al. (1996) argue that BPR's striving for ahistoricity is ironic given IT's capability for data storage and retrieval, concluding that proponents of BPR 'entice managerial audiences to indulge in acts of cultural-historical nihilism with little or no regard for the consequences' (p. 54). Willmott & Wray-Bliss (1996) are concerned about:

> a reengineered future comprising of an increasing emphasis upon technology, markets, competition, individualism, and hierarchical control at the expense of an appreciation of interdependence and community: a future with spiralling

> numbers of people redundant and unemployed; with people having even less control over their work and lives; and the continual restructuring of commercial and public institutions around market lines.... (p. 83)

The concerns voiced about BPR would seem to be equally pertinent to TQM, and indeed the language of customers and markets and intensification of work (for those lucky enough to have it) is common to critiques of both TQM and BPR, which is not altogether surprising given that the authors who were critical of TQM overlap with the authors who are critical of BPR.

2.2.5.1 BPR and TQM

BPR and TQM have been posited as opposites on the basis that TQM represents continuous improvement and BPR represents innovation and discontinuous change (table 2.3), although Flood (1993) considers that BPR is a special case of TQM in its broadest sense.

	Improvement	Innovation
Level of change	Incremental	Radical
Starting point	Existing process	Clean slate
Frequency of change	One-time/continuous	One-time
Time required	Short	Long
Participation	Bottom-up	Top-down
Typical scope	Narrow, within functions	Broad, cross-functional
Risk	Moderate	High
Primary enabler	Statistical control	Information Technology
Type of change	Cultural	Cultural/structural

Table 2.3: improvement and innovation (Davenport 1993)

The quality management tools outlined in this section are aimed at improving customer satisfaction, but fall short of the requirement for radical change in which a breakthrough is achieved. This requires a 'breaking of the china' (Johannson et al. 1993) and reassembly, in which old processes that have evolved over time are broken apart and put together as a set of six or seven core processes. This approach requires that fundamental questions concerning purpose (why) are asked, an issue that can be addressed using a soft systemic approach (Vidgen et al. 1994; Flood 1995).

This author considers that, in its broadest sense, TQM can be seen as incorporating BPR. However, in practice TQM is often reduced to a quality management system based upon ISO9000 driven more by a desire for accreditation rather than quality improvement. In such situations it is quite possible that TQM will be an impediment to BPR. This is a theme that will be re-visited during the fieldwork and in the conclusions of the thesis.

2.2.6 Summary

There are a range of approaches that might be adopted to the development of the ISDM/Q. One way to approach the issues associated with the introduction of a QMS into IS development might be to pursue a narrow view of QA with the aim of ensuring conformance to specification through defined and managed processes that produce consistent products. Alternatively one might decide to take a more fundamental approach and start from what customers demand of the product and expect of the supplier. It was argued in chapter 1 that the application of TQM to software development has tended to focus on the supplier's view of the development process rather than on the product in use and the customer - indeed the author would argue that this difference in emphasis is one of the characteristics that distinguishes IS development from software engineering.

Although this research is not concerned directly with service quality, it seems that a customer service orientation would be an important aspect in the creation a TQM culture. The research is concerned with quality rather than business process redesign (BPR), but the similarities of the two approaches and the current vogue for BPR (although at the time of writing there are signs that the star of BPR is beginning to wane) mean that some reconciliation should be made in this research.

In the next section different approaches to IS development are reviewed, providing a basis for a discussion of how IS and software development practice has been integrated with TQM methods and ideals.

2.3 Approaches to IS Development

2.3.1 Taxonomies of IS development methods

Hackathorn & Karimi (1988) propose a framework for comparing Information

Engineering methods which uses two dimensions: breadth and depth. Breadth includes the subheadings organizational analysis, strategy-to-requirement transformation, logical systems design, logical-to-physical transformation, and systems implementation. Depth is defined to be a 'conceptual-to-practical' dimension in which the conceptual basis for the method is investigated together with the practical tools available for applying the method. This framework is one-dimensional in terms of its underlying assumptions. For example, organizational analysis is concerned with the 'mission and nature' of the organization and with the production of a 'concise, accurate, and formal statement of the organizational strategies that will be useful in the second phase' (Hackathorn & Karimi 1988, p. 206). Given such a view of organizational strategy it is perhaps not surprising that Hackathorn & Karimi resort to techniques such as entity-relation modelling and process modelling for the definition of an information systems architecture.

Wood-Harper & Fitzgerald (1982) provide a broader taxonomy of approaches to systems analysis in which they consider the paradigmatic assumptions that underlie the following approaches: human activity systems (soft systems); participative (e.g., ETHICS); traditional (based on the work of the National Computing Centre - NCC); data analysis; and structured systems analysis approaches. Hirschheim & Klein (1989) extend Wood-Harper & Fitzgerald's work by using the four paradigm framework of Burrell & Morgan (1979) to explore the different paradigms underlying IS development methods and Iivari (1991) has conducted a paradigmatic analysis of contemporary schools of IS development, such as software engineering, database management, and socio-technical.

Bickerton & Siddiqi (1992) provide a classification of requirements engineering methods (figure 2.2) in which they extend Hirschheim & Klein's (1989) taxonomy of IS development methods by stepping outside of the four paradigm framework of Burrell & Morgan (1979) to incorporate ideas from postmodernism (Lyotard 1984) and actor network theory (Callon et al. 1986). In the context of figure 2.2, the framework of Hackathorn & Karimi, which considers development methods based on the information engineering paradigm (Martin 1986), is a good example of a *unitary/hard* approach to IS development. in which the assumption is that the organization uses IT to achieve some functional goals set by the organization's management. In such an approach the IS development effort is aimed primarily at achieving business benefits with little consideration of users, who are not considered until a later stage in the development life-cycle.

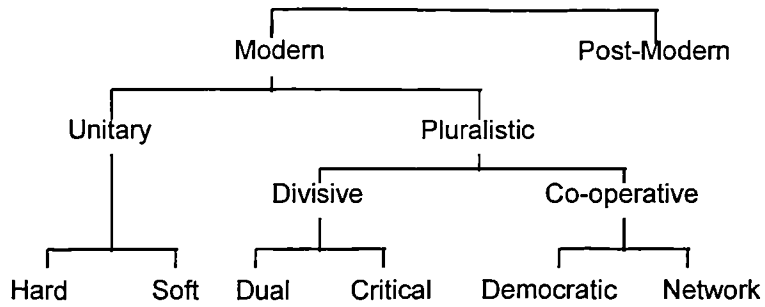


Figure 2.2: a taxonomy of assumptions for requirements analysis (Bickerton & Siddiqi 1992)

The *unitary/soft* approach questions the functionalist basis of hard approaches, particularly with respect to the means-ends orientation. The soft systems methodology (SSM) is often cited as an exemplar of social relativism (Checkland 1981; Checkland & Scholes 1990). The *dualistic* approach assumes a basic conflict between the owners of the means of production and the workers and has formed the basis for much of the IS research in the Scandinavia tradition (see Bjerknes et al. 1987). A *critical* approach to IS development is based on the ideas of the Frankfurt School and more specifically Habermas' knowledge interests, particularly the emancipatory interest (Habermas 1972). With the *democratic* approach to IS development power is assumed to be in the hands of the members of the organization, but exercised through representatives such as management. Politics and conflict are managed through a range of tactics such as avoidance, compromise, negotiation, competition, accommodation, and collaboration (Thomas 1979). For example, combining SSM and joint application development (JAD) would be an effective way of achieving democratic development, although it could be criticised for failing to address issues of power and emancipation (i.e., it is lacking a critical perspective).

The *network* approach has been developed from Latour & Woolgar's (1979) work in the sociology of scientific knowledge and is known generically as actor network theory (ANT) (Callon et al. 1986). Although ANT can be used to understand how IT is adopted (Vidgen & McMaster 1995; Monteiro & Hanseth 1995) the author is unaware of evidence that ANT is being used to inform and guide the development of information systems and IS development methodologies. *Post-modernist* approaches to IS development are difficult to define and identify. Bjorn-Andersen (1988) considers the implications of post-modernism for IS development and Goguen's (1992, 1994) work has been informed by language games and local knowledge (Wittgenstein 1958; Lyotard 1984).

Given that the scene has been set by the broad taxonomy of figure 2.2 specific IS development methods are now reviewed in more detail.

2.3.2 IS development methods

2.3.2.1 Structured methods and O-O analysis

From the early work of DeMarco (1979) through the 1980s structured methods have become widely used as means of managing and conducting IS development. Common characteristics of structured methods are that they allow projects to be broken down into a sequence of well-defined activities and that diagrammatic modelling techniques are used to represent organizational requirements (analysis) and system design. An exemplar of the structured approach is SSADM (structured systems analysis and design method), which is the most widely used IS development method in the UK (Goodland & Slater 1995). SSADM contains:

- a process model, which breaks system development activity down into modules, stages, and steps;
- a product breakdown structure, which specifies the deliverables to be produced;
- a set of diagrammatic and non-diagrammatic techniques that are used to represent the analysis and design of an IS.

While providing some limited support for prototyping (*specification* prototyping) SSADM version 4 adopts an essentially waterfall model of the system development life-cycle. As SSADM develops it is expected that there will be more effective support for other life-cycle models, such as iterative and evolutionary development (figure 2.3), and rapid applications development, such as DSDM (dynamic systems development method). There are many variants on the structured methods theme, including Information Engineering (Martin 1986) and the Yourdon method (Yourdon 1989).

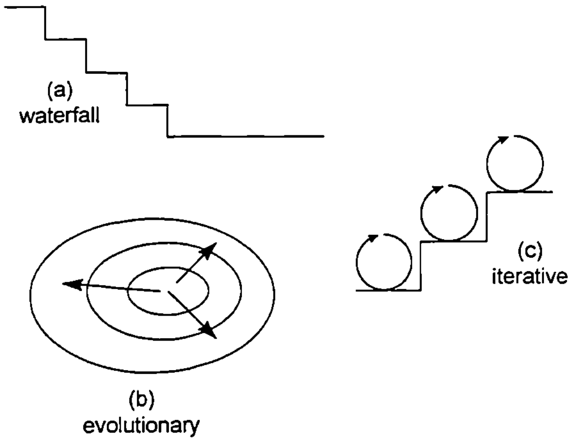


Figure 2.3: life-cycle approaches to IS development

Common to structured methods is a three-schema framework in which separate models of data, processes, and dynamics (events) are made. With the success of Object-Oriented (O-O) programming languages such as Smalltalk (Goldberg & Robson 1983) there has been a significant level of interest in moving O-O concepts up-stream into systems analysis (Coad & Yourdon 1991a; Martin & Odell 1992; Rumbaugh et al. 1991). However, O-O analysis is still focussed on functional requirements and can also be categorized in the taxonomy of figure 2.2 as unitary/hard. Martin & Odell (1992) are characteristically bullish about the benefits of O-O analysis coupled with O-O technologies, arguing that there will be improved reusability, better reliability, easier maintenance, improved machine performance, faster design and easier programming.

2.3.2.2 Socio-technical approaches

Structured methods tend to be founded in reductionism and to place a large emphasis on functional requirements that can be specified using rather simple diagramming notations (e.g., data models and data flow diagrams). In the ETHICS method it is recognized that there is a need to integrate technology, the organizational environment, people (with values and needs), and tasks (which require motivation and competence) (Mumford & Weir 1979; Mumford 1983). Job satisfaction and participation are central themes of the method. Participation is considered in some detail and problems are recognized that relate to trust, selection of participants, communication, conflicts of interest, stress, roles of participants, and rapidly changing technology (Mumford 1983, pp 31-35). In designing work for job satisfaction there should be good knowledge, psychological, efficiency, task structure, and ethical fits between an employee's needs and job experience. Job satisfaction needs are typically diagnosed using questionnaires in the early stages of work design. The last stage of the ETHICS method is to perform an evaluation to consider variances in efficiency and job satisfaction. In the conclusion, Mumford (1983) draws a parallel between ETHICS and Japanese quality circles on the basis that all groups must be involved in the design process (p. 106). This is perhaps an unfortunate comparison given that it has been noted above that quality circles have fallen into disuse as an ineffective form of organization for quality improvement.

Socio-technical approaches, such as ETHICS, that draw upon the ideas and methods developed by the Tavistock Institute have been criticised for being managerialist - organizations benefit from the increased efficiency that results from socio-technical design (Bansler 1989). However, the ETHICS method is certainly useful insofar as it provides a contrast between social and technical interests, although it seems that the technical interests of ETHICS are technical in the sense of a Habermasian knowledge interest rather than a concern with technical artefacts per se.

Eason (1988) comments that ETHICS has not been adopted widely and highlights two problems with ETHICS. Firstly, ETHICS needs an expert, such as Mumford, to support users and designers in a socio-technical design process and:

> The second problem is the degree to which it can be integrated with traditional data processing systems design. There are few points of contact and it is difficult to see how both processes can be undertaken in the same development. (p. 39).

This author believes that the first criticism could be levelled at any IS development method. The second point is more convincing and is related to the lack of a specific consideration of information technology and technical artefacts. Eason (1992) identifies four problems with computer systems development: technology push, the waterfall model; the dominance of technical specialists, and the use of rational technical language. Eason proposes a set of principles for user-centred design that address the integration of work and technology, user-centred design structures and design processes, and system implementation. An emphasis is placed on users taking ownership of the computer system and achieving mastery of the technology and greater competence in their organizational work (Eason 1992). A strong theme that emerges from Eason's work is the need for prototyping and evolutionary development approaches to the system development life-cycle.

Organizational view	Work view
Analytic assumption	*Analytic assumption*
People produce human error	People discover problems and solve them
Design assumptions	*Design assumptions*
Deskilling is desirable	Skill development is desirable
Routine work, rote thinking desirable	Development of knowledge, understanding, deciphering is central to skill
Flexibility = interchangeable jobs	Flexibility = skilled people
Standard operating environments are necessary to the business	Collaboration and collaborative learning take place in communities
Social interaction is non-productive	Communities are funds of knowledge
Automation produces reliability	Skills through learning produces reliability
Consequence	*Consequence*
Learning is not encouraged	Learning is supported

Table 2.4: organizational and work views (Sachs 1995)

The issue of a rational description of work has been challenged by Sachs (1995), who describes a case study of a Trouble Ticketing System (a database for recording and scheduling jobs) in which new technology and new working practices are introduced which, on the face of it, should have lead to gains in efficiency. Unfortunately the design of the technical system gave insufficient attention to how work was actually achieved in practice leading to work being performed less efficiently. Sachs (1995) contrasts an organizational view with a work view (table 2.4).

Although prototyping, evolutionary development, and participative design are common themes of the socio-technical approach, Kyng (1995) points out that prototypes of the user interface are not sufficient and do nothing to help bridge the gap between the technical world of the designer and the professional world of the user (p. 55). The socio-technical approach is best seen as a joint exploration and creation of work and technology rather than a reductionist view of improved requirements capture and rapid application development. Human computer interface issues are important and relevant but are perhaps better seen within the context of computer supported co-operative work (CSCW) (Grudin 1991; Kyng 1991) which takes greater account of the interaction between people as mediated by computer-based technical artefacts. To reinforce a respect for the difficulties of design Ehn & Kyng (1987) recommend:

> Designers should restrict their activities to a few domains of application, and they should spend at least a year or two getting acquainted with a new area before doing actual design. (p. 56).

Although organizations might not be in a position to take this advice literally, it is a salutary reminder of the difficulty of understanding, let alone describing work. From the viewpoint of IS quality the socio-technical tradition highlights the need to consider the quality requirements, typically expressed as job satisfaction, of those whose work is changed by the introduction of new technology.

2.3.3 Systems approaches for IS requirements analysis and development

2.3.3.1 Soft systems methodology (SSM)

SSM is a strong problem-solving methodology with a well-defined theoretical provenance (Checkland 1981) and considerable experience in use (Checkland and Scholes 1990; Wilson 1990), including the information system development arena, as reflected in the Multiview methodology (Avison & Wood-Harper 1990, 1991) and FOAR (Schafer et al. 1988).

SSM has achieved widespread application in a variety of domains, such as manufacturing industries (Checkland (1990) at ICI and BP) and health care (Keleher & Cole 1989). Mingers & Taylor (1992) have performed a survey of the use of SSM in practice from which they conclude that 'SSM is a practical and successful general purpose methodology which can be used successfully by a wide range of people in their ordinary jobs' (p. 331). The respondents noted that they thought SSM was time-consuming and that it might not be suitable for managers. Mingers & Taylor (ibid.) state that training is needed - something more substantial than a one-day course - and that the language of SSM can be an obstacle to its acceptance.

There has been considerable interest in combining SSM with structured methods and debate concerning the 'grafting and embedding' distinction (Miles 1988) - should SSM be grafted onto the front of a structured method or should structured methods be embedded within a soft systemic approach to IS development? This topic has been the subject of some debate and featured in a special edition of the Systemist where concerns about the paradigmatic mismatch between hard and soft approaches was raised (Jayaratna 1992; Wood 1992). Fitzgerald (1992) argues that SSM should be performed first and that any linking between SSM and IS development methods should be restricted to the 'enhanced education and understanding of the actors' (p. 127) since to do more would be to change SSM such that the very benefits of a soft approach would be lost.

2.3.3.2 Strategic assumption surfacing and testing (SAST)

Stakeholder analysis is part of Mason & Mitroff's (1981) strategic assumption surfacing and testing (SAST), which comprises the following stages: formation of groups who identify stakeholders; surfacing of assumptions; dialectical debate; and synthesis. SAST has a provenance in the enquiring systems of Churchman (1971, 1979) and has been applied in conjunction with SSM by Flood & Jackson (1991) and proposed as a foundation for IS quality by Vidgen (1994).

2.3.3.3 Total systems intervention (TSI)

The total systems intervention (TSI) approach is a meta-framework that helps the analyst in selecting system methodologies, in varying combinations, to suit the purpose of a specific intervention (Flood & Jackson 1991). The work has been extended by Flood (1993, 1995), who has paid particular attention to the application of TSI to quality improvement.

In this author's opinion there are practical difficulties associated with TSI. The first difficulty is TSI's all-embracing frame, which makes it difficult for an analyst to achieve a level of competency in the wide range of disparate different methodologies and methods. Although, one person would not be expected to be proficient in all the methods, it does raise the problem of how an *informed* choice of method would be made. The second concern with TSI is that it is a general purpose approach which does not address information technology in any specific way.

2.3.3.4 *Multiview*

In one sense Multiview (Avison & Wood-Harper 1990, 1991; Wood-Harper & Avison 1992), a multiple perspective and contingent methodology for computer systems development, is a domain specific version of TSI. Multiview consists of five stages: human activity modelling (founded in soft systems thinking), information analysis (structured systems analysis), socio-technical analysis (ETHICS), human computer interaction (HCI), and technical (detailed technical design of data and processing). Thus Multiview addresses the issue of technical design directly, although it could be argued that there is no critical element and that Multiview constitutes a paradigmatic mismatch of hard and soft methods, as noted in the debate concerning the combining of hard and soft approaches to IS development.

2.3.4 IS requirements

Systems analysis is distinguishable from software development insofar as one is facing the organization and is concerned with what is to be done while the other is concerned more with how it will be achieved. The IS development methods described in this section are all concerned with systems analysis, but not all of the methodologies address the construction of technical artefacts. Requirements analysis is a natural meeting place of ISD and TQM since "customer" needs are fundamental to systems analysis and quality management.

IS requirements are commonly categorized as functional or non-functional. Functional requirements address what the software can do while non-functional requirements (NFRs) are concerned with overall qualities of the system, such as reliability and performance. The ISO9126 standard, which identifies a set of quality characteristics, is effectively a list of NFRs for software. Kotonya & Sommerville (1994) identify the following problems with NFRs within the requirements engineering tradition:

- some NFRs are related to a design solution that is unknown at the requirements stage;
- some NFRs are highly subjective, especially those associated with human engineering issues;

- NFRs have great diversity;
- NFRS and functional requirements are related - methods that separate them out make it difficult to see the correspondence between them;
- NFRs tend to conflict and therefore need to be treated as trade-offs.

Most IS development methods focus on functional requirements and tend to treat NFRs as secondary issues. Finkelstein et al. (1992) propose an approach to NFRs in which the environment of the computer system can be considered with respect to specific viewpoints, thus taking into account the roles and responsibilities of the various participants. Kotonya & Sommerville (1994) criticize the viewpoint approach for not providing an integrated view of functional and non-functional requirements, for taking a narrow view of NFRs (typically restricted to efficiency, response time, etc.), for treating NFRs globally (specific parts of the system may be associated with specific NFRs), and for not addressing the issue of trade-offs between NFRs.

Many of the problems of NFRs can be seen in structured methods, such as SSADM, which places great emphasis on capturing functional requirements, supported by techniques such as data flow diagramming, data modelling, and a requirements catalogue. Although NFRs are captured in SSADM (and can be associated with functional requirements or entered separately as global constraints) there is no systematic approach to capturing NFRs, no method support, and no mechanism for trading-off conflicts between NFRs.

2.3.5 Summary

The taxonomy in figure 2.2 demonstrates that there is a wide range of methods and methodologies available to the IS developer and hence as a basis for the ISDM/Q. In practice IS development is based on those methods that are categorized as unitary/hard, such as structured methods and O-O analysis. In the review of socio-technical approaches to IS development it was apparent that functionalist and reductionist approaches to IS development are in many situations not going to be sufficient and that if this perspective on IS development is ignored then although the technical artefacts might conform to the *functional* specification the IS might still fail. Furthermore, variant life-cycles, such as incremental development, and the use of prototyping are at best a partial solution while they are deployed within a functionalist paradigm.

However, it is also clear from the literature review that there are misgivings concerning the mixing of different paradigms within a single IS development methodology. This is an issue that will be returned to in chapter 4. Given that quality management and IS development have been reviewed, the next section explores the extent to which quality approaches have been applied to software and IS development.

2.4 Software and IS quality management

The previous sections have addressed quality management and IS development as largely separate topics. This section is concerned with the application of a quality approach to the development of software and information systems.

2.4.1 Software quality assurance

Software development has a significant element of design and hence ISO9001 is in most cases the applicable QA standard. Software development managers have voiced concern regarding the applicability of a generic QA standard to the software industry and the ISO response was to issue a set of guidance notes which address software QA specifically. These notes are known as ISO9000-3 - they do not replace the ISO9000 series but provide guidance on how the series is to be interpreted in a software development context. The ISO9000-3 guidance notes also highlight differences between software and other products: software is an intellectual object; the development process has particular characteristics; replication gives an exact copy; software does not wear; once a fault is fixed it will not re-occur (Gillies 1992). The Department of Trade and Industry (DTI) launched the TickIT programme to promote awareness of the need for accreditation and QA in the software development process (TickIT 1990).

With regard to monitoring and controlling software quality Fenton & Whitty (1995) consider measurement to be 'the only effective way for assessing the impact of quality assurance practices on software development' (p. 2). Fenton & Whitty warn of abuses of measurement and basic measurement flaws, such as a lack of definition of the parameters and measures (Fenton (1991) has explored the basis of measurement and rigorous metrics in depth). The ideas of TQM, which were developed originally in manufacturing industries, have been adopted by Hitachi in the "software factory". Yasuda & Koga (1995) describe a V-shaped process in which design and testing processes pivot around coding (figure 2.4).

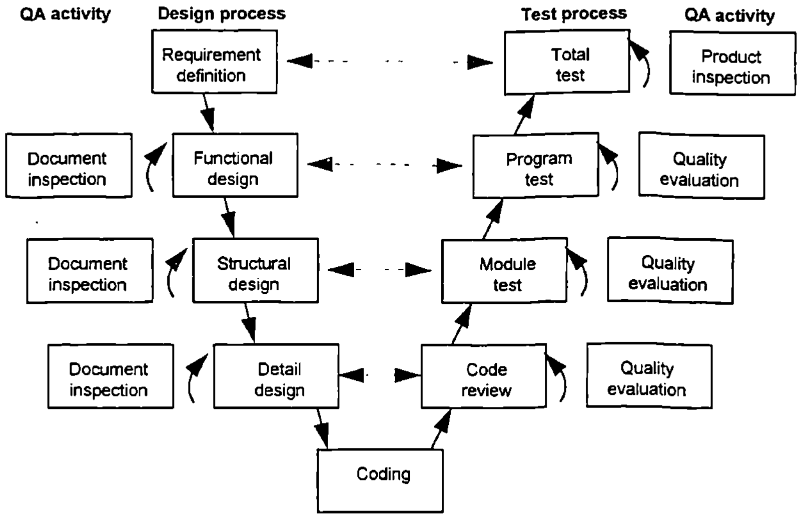


Figure 2.4: SQA in the software factory (Yasuda & Koga (1995), fig. 18.2)

The SQA and software metrics literature is concerned primarily with basic qualities, the must-be attributes, such as reliability, usability, maintainability (ISO9126 1991), that are unlikely to be articulated by customers. Furthermore the SQA process of figure 2.4 is founded on a waterfall software development life-cycle that might not be appropriate to different life-cycles (figure 2.3). In this author's opinion SQA has placed an over-emphasis on the supplier's view of quality, which is grounded in an engineering tradition, to the detriment of the customer.

2.4.2 Process capability

Process maturity and capability models, which overlap with SQA and ISO9000, play a significant role in software quality and software process improvement initiatives. The Software Engineering Institute (SEI) at Carnegie Mellon has built on the work of Humphrey (1989) and developed a range of assessment techniques that allow organizations to evaluate their capability on a one to five scale (figure 2.5).

Each level of the CMM contains a set of key process areas, such as requirements management and configuration management, against which an organization is assessed. Humphrey considered the majority of organisations to be at levels 1 and 2 (Humphrey, Kitson and Kasse 1989), with some having attained level 3. Although individual software teams were found to be working at levels 4 and 5, no complete organisations could be found working at these levels. More recent evidence shows that that part of IBM developing software for NASA has attained level 5 (Fenton & Whitty 1995).

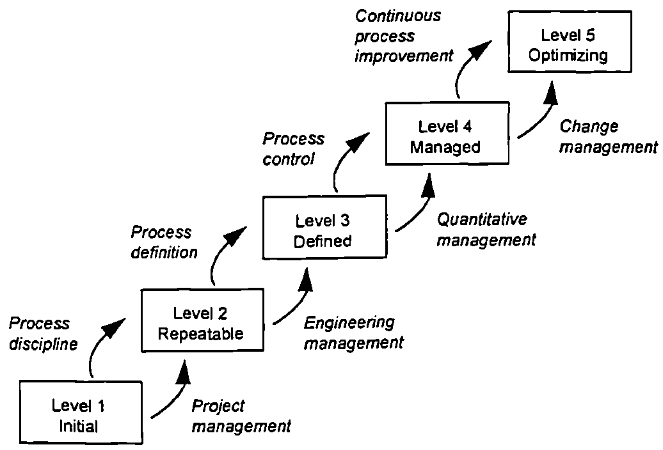


Figure 2.5: Capability maturity model (CMM)

The SEI's maturity model has counterparts in Europe, most notably Bootstrap and SPICE. Bootstrap has been funded through the ESPRIT programme and differs from the CMM in two areas in particular: firstly, it is possible to apply Bootstrap to parts of an organization, such as individual projects, and secondly, Bootstrap returns a score in the range 1 to 5 (it is possible to score, say, 2.8 with Bootstrap whereas the CMM deals only in whole numbers - the organization is either level 3 or it is not). The SPICE programme (Software Process Improvement and Capability dEtermination) is an international initiative sponsored by ISO with the intention of building on and integrating the CMM, Bootstrap and ISO 9000-3 initiatives.

Process capability assessment is of particular significance because purchasing organizations can require software suppliers to have reached a certain level (for example, the U.S. Department of Defence requires suppliers to have attained level 3). However, it is difficult to demonstrate that higher rated organizations produce better quality software and the CMM is not without critics (Hetzel 1995). As with ISO9000 series certification, the process capability assessments are generating a lucrative market for consultants and assessment bodies and smaller supplier organizations may well be engaging in accreditation on a "must-do" basis rather than entering into a spirit of continuous improvement.

2.4.3 Software metrics

Fenton (1991) advocates a rigorous approach to *measurement*, which he defines as a 'process by which numbers or symbols are assigned to attributes of entities in the real world in such a way as to characterize them according to clearly defined rules' (Fenton & Whitty 1995, p. 6). The assignment of numbers constitutes a *measure*. Fenton & Whitty (1995) define a *metric* as a proposed measure, which can be called a measure if it faithfully characterizes the attribute of interest. Typical metrics include lines of code (LOC), which is a measure of program length, but not complexity, and McCabe's cyclomatic number, a metric that might qualify as a measure of complexity.

Metrics can be applied to processes (e.g., requirements capture), products (e.g., source code, requirements specification, testing plan), and resources (e.g., CASE tools, people). Internal attributes of processes, products, and resources can be measured in the context of the entity concerned, such as the length of a program, or the man-hours (time) taken to prepare a requirements specification. External attributes need to be measured in context; for example, reliability depends not just on the product but also on the particular experiences of a user. The majority of external attributes can only be measured indirectly and the metrics used might not be a good representation of the attribute of interest.

A common theme of software quality metrics is to map from a desired quality factor, such as reliability, to a set of criteria (for example, reliability maps to consistency and to completeness), and to then map criteria into metrics. The standard ISO9126 (1991) is concerned with software product evaluation and provides definitions of quality characteristics, such as reliability, which is defined as:

> A set of attributes that bear on the capability of software to maintain its level of performance under stated conditions for a stated period of time

ISO9126 does not specify criteria and metrics to support the quality characteristics, stating that:

> Evaluating product quality in practice requires characteristics beyond the set at hand, and requires metrics for each of the characteristics. The state of the art at present does not permit standardization in this area (p. 13).

Similarly, the IEEE1061 (1992) standard, "Software Quality Metrics Methodology", does not specify a set of product metrics, focusing instead on the process of establishing quality requirements and identifying relevant metrics.

This means that any organization interested in implementing a metrics programme will firstly need to define its products and processes, which indicates that the organization should have accomplished level 3 of the CMM, and secondly develop metrics that are relevant and practicable given its particular situation and objectives.

2.4.4 Frameworks for deriving software metrics

Generic models of software quality that are structured into hierarchies have been identified by McCall et al. (1977) and Boehm et al. (1978). These generalized models have been extended to take account of the specific context in which metrics will be used, with three approaches being described in the literature by Basili (1995): software quality metrics (SQM), goal/quality/metric (GQM), and quality function deployment (QFD). Each of these approaches is concerned with the selection of metrics that reflect business objectives.

2.4.4.1 Software Quality Metrics (SQM)

The SQM was developed by the Computing Services Association (CSA) and documented in a briefing note. It is a framework for selecting and categorizing metrics within three areas: *size* (e.g., function points), *product* quality (e.g., number of faults found during system test, number of customer change requests), and *process* quality (e.g., team productivity). The needs of the business are used to drive the selection of appropriate metrics. Möller & Paulish (1993) conducted a review of best practice with respect to software metrics and concluded that metrics can be used to improve software quality, but only as part of a cycle that involves business objectives, quality improvement goals, metrics to measure progress, and a feedback loop to identify process improvements.

2.4.4.2 Goal/Quality/Metric

The goal/quality/metric (GQM) model involves three stages: *goals*, which addresses the purpose of evaluation; *questions*, which are quantifiable; and *metrics*, which are used to identify data collection requirements and to answer the questions raised (Basili & Weiss 1984). Basili (1995) states that for an organization to measure in a purposeful way it is necessary that it 'specifies the goals for itself and its projects', 'traces these goals to the data that are intended to define these goals operationally', and 'provides a framework for interpreting the data in order to understand the goals' (p. 24). In line with Möller & Paulish (1993), Basili (1995) also sees metrics as part of a quality improvement paradigm (Basili & Rombach 1988) that involves planning, execution, and analysis & packaging in a closed loop. Basili (1995) distinguishes between the project organization and the "experience factory", which is concerned with the off-line analysis of project experiences, 'acting as a repository for such experiences and supplying that experience to various projects on demand' (p. 26). This institutionalization of organizational knowledge is also identified by Curtis (1992) who argues that the CMM allows organizations to create a mechanism for learning from previous project experience (for mature organizations at level 3 and higher this experience will be captured in part through the use of quantitative metrics).

Basili (1995) supplies an example of a process goal:

> Analyze the **system test process** for the purpose of **evaluation** with respect to **defect slippage** from the point of view of the **corporation** (p. 39, original emphasis)

The construction of the goal involves a *purpose* (what is to be done and why), a *perspective* (e.g., the project manager's, the corporation's), an *environment* to define the context of the study (e.g., process factors, problem factors, people factors, methods, tools, constraints). There is a strong resonance with the CATWOE mnemonic of SSM in the formulation of goals in GQM. Although the GQM approach is rather much in a functionalist tradition of consensus and multiple views of a singular objective reality, it does indicate an awareness by software engineers that metrics and quality are contextual.

2.4.4.3 Software quality function deployment (SQFD)

SQM and GQM have their roots in the software engineering tradition, while QFD (described in section 2.2.3 above) was developed in the manufacturing industries in Japan. Experiences of adapting QFD for software development have been described by Zultner (1990, 1993) and Betts (1990), although these reports contain little practical guidance. Evidence that QFD is gaining acceptance in software development is provided by Haag et al. (1996), who argue that QFD is the implementation vehicle of TQM. Haag et al. conducted a survey of the usage of QFD by commercial software vendors and report that there is increased uptake of QFD use and that the organizations concerned have achieved benefits from Software QFD (SQFD) that include:

- improved user involvement;
- shortened life-cycle times;
- improved communications with users, technical personnel, and managers;
- avoided of loss of information;
- encouraged team involvement;
- provided a preventative tool for improving quality.

The approach adopted by Zultner is to extend QFD at the requirements analysis stage, recognizing that:

> For software, customer demands are the requirements of users and other stakeholders in the project. As software development projects often must serve many classes of users and stakeholders, it is necessary to clearly understand who has what requirements, and to what extent. Users must first be identified, and their requirements determined and prioritized, before beginning work on the A-1 matrix. (Zultner 1990, p. 134)

The standard form of QFD begins with the “A1 matrix”, in which customer requirements are translated into technical requirements. Zultner proposes that additional matrices be used to identify users and user characteristics (Z-0) and users and user requirements (Z-1). Software engineering-specific matrices are added downstream to assist the developer in translating requirements into entities and processes, reflecting the structured methods approach. Betts (1990) argues, with little supporting evidence, that these matrices can be adapted for Object-Oriented requirements and design methods.

Although it is often argued that software is a special case, this author believes that this due more to tradition than to some intrinsic properties of software. With tangible products one is perhaps more used to thinking of a single customer group with unitary characteristics, but in some ways this is no more true about a car exhaust than it is about software. In common with SQM and GQM, SQFD starts with customer requirements and deploys these requirements through the product life-cycle. Any compromises are made in the context of customer requirements and not for technical convenience.

2.4.5 User satisfaction

There is a body of work concerned with the assessment of "user information satisfaction" (UIS) in IS research. Gallagher asked users to attach estimates of the dollar value of the products of an IS (Gallagher 1974); another study used a 20-item measure of user satisfaction, in which the items were derived from a literature review and structured interviews (Jenkins & Ricketts 1979). This research excluded the service aspect of IS development and support, focusing wholly on the IS. Pearson conducted extensive interviews with user managers and identified 39 factors which were analyzed in four adjective pairs (e.g., for "reliability of output information" two of the pairs are consistent/inconsistent, sufficient/insufficient) (Bailey & Pearson 1983). Responses were gathered using a questionnaire that employed the semantic differential technique (a 7 point scale). In addition to the four pairs, for each item the categorizations satisifed/dissatisfied and important/unimportant were included. Ives et al. (1983) replicated the Pearson experiment using a larger sample size with the aim of reducing the length of the Pearson instrument and producing a standard short-form that could be applied universally.

The instrument produced by Ives et al. (1983) contained categories such as relationship with EDP staff, confidence in systems, confidence in output, reliability of output, attitude of EDP staff, volume of output, flexibility of system, documentation, accuracy of output, and communication with EDP staff. Ives et al. commented that:

> This article presents significant progress toward development of a standard measure of user information satisfaction. Whether or not this instrument is chosen, the authors encourage the MIS research community to choose a standard instrument for measuring UIS. (p. 792)

The UIS approach is to create a general purpose instrument that can be used as a surrogate for IS effectiveness. This is a bold attempt to relegate context-related issues to the second division, since any specific issues would need to be translated and filtered through the crude mesh of generalized issues.

Goodhue used the job satisfaction tradition and a theoretical basis that distinguishes between attitudes and beliefs (Goodhue 1986). IS satisfaction is concerned with attitudes and subjective characteristics, the feelings that a user has about the IS, whereas IS satisfactoriness is concerned with the individual's objective beliefs about the fit between task requirements and IS functionality. Goodhue argues that we should not ask whether a system contains accurate data, which the user may not be able to answer objectively, but whether the system contains data that is accurate enough for his tasks (Goodhue 1986, p. 192).

The UIS tradition emphasizes the individual user's satisfaction with an IS through correspondence of task requirements and the facilities of the IS (albeit in a general manner). The orientation is positivist with the aim of finding an underlying causal model that will explain how user satisfaction comes about. The focus is on the individual and the primary user of the IS. Although this might be useful, it does not address group-level and organizational-level issues, and is not appropriate for secondary and tertiary users of an IS. The UIS model might be useful in finding out where things have already gone wrong, but awareness will need to be supplemented by an understanding of the context if the UIS model is to be used to inform IS development.

2.4.6 IT service quality

Service quality is of particular importance to industries that provide intangible products, such as the entertainment industry, parcel delivery, and insurance services, but all products, regardless of their tangibility, have an implied service aspect. In some cases the service element might be limited to providing a timely replacement of faulty units with no supplier/customer interaction at a personal level, and indeed a limited service view and a focus on a technological product have typified software development. The delivery of a product, such as a suite of software, marks the end of a product development phase, which is followed by implementation, production support, and maintenance. In this author's opinion, these post-development activities should be treated as being of at least equal importance as the original development process and viewed as customer service rather than a tedious and distracting maintenance activity that gets in the way of "real" work. In support of this position it can be argued that a customer service metaphor focuses developers on a continual process of assessing and understanding the context in which their products are deployed (Vidgen et al. 1993).

Watson et al. (1993) argue that IT departments have three roles - system developer, infrastructure, and service provider. Traditionally IT departments have focused on system development and have paid little attention to the provision of a service, which is becoming more pertinent as IT 'has moved from being a tool for automating clerical processes to a device for gaining competitive advantage, sharing expertise, supporting decision-making, creating electronic markets and so forth' (Watson et al., p. 264). Pitt et al. (1995) have adapted the SERVQUAL instrument and assessed its performance as a measure of IS effectiveness; they conclude that the SERVQUAL instrument is applicable to the IS area and promote the idea of a customer service life cycle constituted of four major phases: requirements, acquisition, stewardship, and retirement (Ives & Mason 1990). Rands (1992) also investigates the idea of IT as a service operation and proposes a framework for managing IT service quality, arguing that 'viewing IT services as multi-dimensional...is a radical departure from earlier approaches to IT' (p. 196). Rands comments that the UIS research suffers from the use of a single scale and a possible technical bias in the questions put to users.

2.4.7 Summary

In rough terms one can distinguish between context-free and context-sensitive notions of quality. Bringing this together with a distinction between software development (engineering of technical artefacts) and IS development (systems analysis of organizational requirements) leads to the framework of figure 2.6.

Although some of the applications of QFD (for example, Zahedi 1995) come close to a context-sensitive approach to IS quality it is done within the context of how technical artefacts can be used to support given and objectively knowable organizational requirements - there is no discussion of why the activity is done, as would be the case with BPR, or with the interpretivism of a soft systems approach.

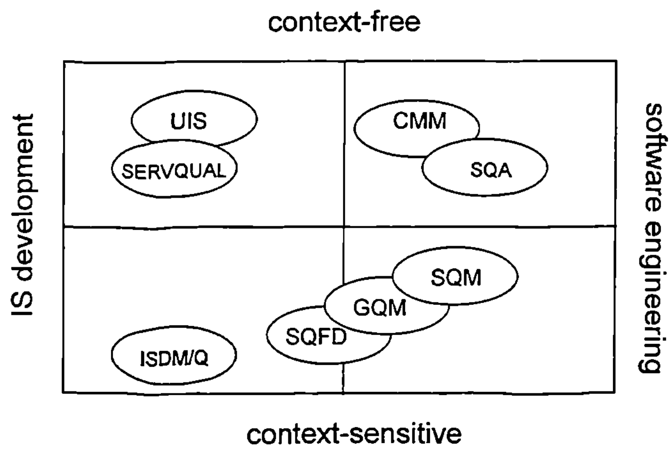


Figure 2.6: approaches to software and IS quality

The proposed location of the ISDM/Q was given in figure 1.4 and it was asserted that there was a gap in IS practice at the intersection of IS development and TQM. This gap can be filled in part by context-free evaluations of IS effectiveness, but in this author's opinion it is the bottom left-hand quadrant of figure 2.6 that needs to be addressed if IS quality is to be achieved. The ISDM/Q is located here and is concerned with a strongly context-sensitive view of IS quality reflecting the view of IS failure as expectation failure adopted in chapter 1. The recognition of multiple stakeholders and the potential for multiple and conflicting sets of interests suggest that the unitary/hard tradition of system development, grounded in a mechanistic metaphor (Morgan 1986, 1993), will not be appropriate as a basis for a quality approach to IS development.

Chapter summary

The origins of quality management were explored in the first section of this chapter, which highlighted the need for quality improvement programmes to address not only tools and methods but also organizational and individual factors. In the second section the intention to adopt a customer/product approach to IS quality, rather than a supplier/process approach was declared. In the third section different approaches to IS development were reviewed, demonstrating that unitary/hard approaches, such as structured methods and O-O analysis, are not necessarily sufficient for the development of quality information systems, particularly with respect to socio-technical issues. It was also noted that the paradigms that inform the different approaches to IS development may prove to be incompatible. In the last section the conclusion was drawn that there is a need for a quality approach to IS development that is adaptable to each specific context that pays due consideration to organizational activity as well as the engineering of technical artefacts. In chapter 4 the foundations of quality are explored in order to develop a framework of ideas that can inform the development of an ISDM/Q.

3

Choice of a research approach

Introduction

In chapter 1 the research theme was introduced and relevant literature was reviewed in chapter 2. This chapter is concerned with the selection of a research approach that is appropriate for the research theme outlined in chapter 1 and detailed in chapter 2. A taxonomy of research methods based on the scientific/interpretivist classification is introduced and a range of research methods and techniques are outlined. It is then argued that this research should take place in an organizational setting and the principal research methods that could be applied to an in-context investigation of IS quality are described in greater detail. An IS research framework is then introduced to assist in the research design (Braa & Vidgen 1995). The structure of the chapter is outlined in figure 3.1.

The issues of what research approaches might be relevant to IS research have been debated in conferences held by two influential organizations: Harvard Business School Research Colloquiua and the International Federation for Information Processing (IFIP) Working Group 8.2. The brief of the 8.2 group is 'The Interaction of Information Systems and the Organization'. The first Harvard Business School colloquium was held in 1983 and included contributions covering management support systems, management of the information systems resource, and corporate strategy. This colloquium was followed up by three further colloquia in which specific approaches to research were addressed, resulting in three volumes of contributions. Each of the volumes is entitled 'The Information Systems Research Challenge', but has a different subtitle: 'Qualitative Research Methods' (Cash & Lawrence 1989); 'Experimental Methods' (Benbasat 1990); and 'Survey Research Methods' (Kraemer 1991). The IFIP WG 8.2 Colloquium 'Research Methods in Information Systems' was held in the UK in 1984 (Mumford et al. 1985), and a further 8.2 Working Conference on the 'Information Research Arena of the 90's', was held in Copenhagen in 1990 (Nissen et al. 1991).

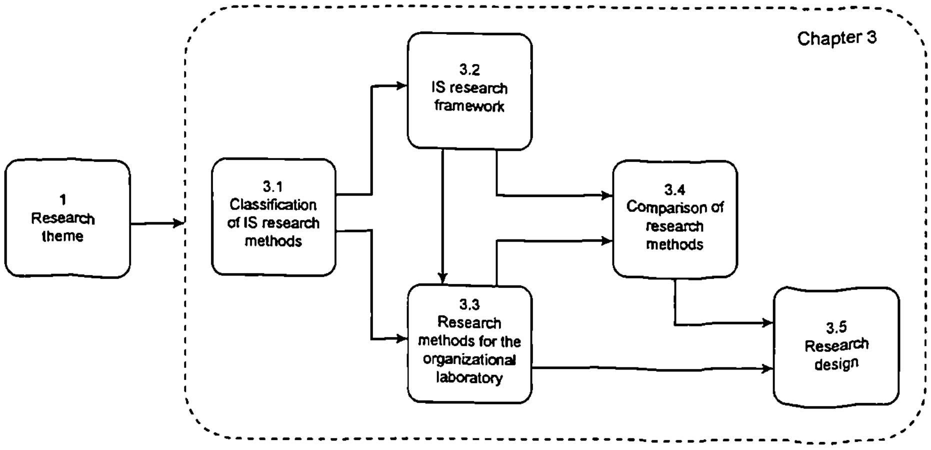


Figure 3.1: structure of chapter 3

Jarvenpaa et al. (1985) argued for the importance of careful design of IS experiments in the interests of internal validity, an issue raised by Campbell & Stanley (1966) and refined later by Cook & Campbell (1979). The predominance of experimental approaches was questioned by Galliers & Land (1987), who argued that information systems is an applied discipline rather than a pure science and that consequently interpretive modes of enquiry are needed. The division between a scientific approach (for example, Jarvenpaa's (1988) response to Galliers & Land) and an interpretivist approach to IS research has been a theme running through the literature on IS research approaches (Hirschheim 1985). This distinction is explored in the next section.

3.1 Classification of IS research methods

Galliers has classified research methods into two categories: scientific and interpretivist (Galliers 1985, Galliers & Land 1987, Galliers 1992). The scientific approach assumes that phenomena can be observed objectively and rigorously; good research is legitimated with reference to the virtues of repeatability, reductionism, and refutability (Checkland 1981). In contrast, the interpretivist approach considers the methods of natural science to be inappropriate where human beings are concerned, and it is recognized that different stakeholders (including researchers) can interpret a situation in different ways. These two views of research can be characterized as science, which is concerned with reducing the area of investigation in order to be able to make reliable predictions, and interpretivism, which is concerned with making a reading of history in order to gain understanding. The scientific and interpretivist approaches to research are summarized in figure 3.2 with respect to assumptions concerning ontology, epistemology, human nature, and methodology.

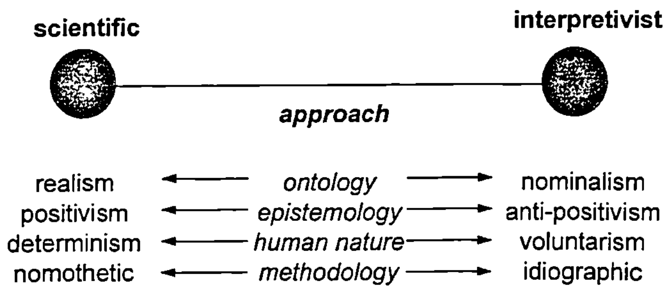


Figure 3.2: scientific and interpretivist approaches to research

The distinction between the scientific and interpretivist approaches is an over-simplification and, to a large extent, a "straw man". Archer (1988), for example, distinguishes between 'positivism', 'non-positivism', in which facts and values are inseparable, and 'normativism', in which scientific knowledge is seen as ideological. Archer also distinguishes between the 'external realism' adopted by positivism, 'internal realism' (the inter-subjective construction of reality) and 'subjective idealism' (each of us constructs our own reality).

Scientific	Interpretivist
Laboratory experiments	Subjective/argumentative reviews
Field Experiments	Action research
Surveys	Descriptive/interpretive
Case studies	
Theorem proof	
Forecasting	Futures research
Simulation	Role/game playing

Table 3.1: IS research approaches (Galliers 1992, p. 149)

However, the straw man of science and interpretivism has informed much of the debate on IS research methods and provides a useful basis for a taxonomy of research methods. For example, Galliers (1992) has classified IS research methods using this distinction (table 3.1). Galliers splits forecasting-futures research and simulation-role/game playing into the classifications that he considers to reflect their underlying ethos. These research methods are now described in overview within the classification of scientific and interpretivist approaches.

3.1.1 Scientific methods

3.1.1.1 Laboratory experiments

Quantitative analytical techniques are used in a laboratory environment where relationships between variables can be controlled. The aim of this method is to produce results that can be generalized to the real world. The choice of the experiment reflects an area of concern, which Dickson et al. (1977) categorize as simulation, small group, man-machine, and prototype experiments. The strength of the experimental approach is that a small number of variables can be studied intensively; the major weakness is that it is very difficult to control all the variables that are assumed to remain constant and that the setting in which laboratory experiments takes place is artificial (for example, students are often used, as in the Boehm et al.'s (1984) experiment comparing prototyping and life-cycle methods of software development).

3.1.1.2 Field experiments

These are experiments carried out in a real-world setting, thus attempting to compensate for the artificial nature of laboratory experiments (Jenkins 1985). A major weakness of this approach is that it is even more difficult to control or compensate for variables that are assumed to be constant.

3.1.1.3 Surveys and structured interviews

Surveys are usually carried out through mail, telephone, or personal interviews (given current technology they could also be carried out through email or the Internet). These techniques provide a snapshot of a situation, the results of which can be analyzed using quantitative and qualitative techniques. A strength of this technique is that large sample sizes can be used to provide the basis for generalization. Surveys are good for describing, but less useful for gaining a deeper understanding of the phenomena captured. It is difficult to eradicate bias in the survey design and the selection of respondents. The validity of the results is also affected by the level of non-response rate.

3.1.1.4 Case studies

This method involves making a detailed description of a situation, thus providing a considerably richer view than the preceding methods. Benbasat et al. (1987) highlight the issue of boundary definition; because the boundaries are not clearly defined at the beginning of the research it is not appropriate to use experimental control of variables. It has been argued that because of different interpretations and lack of control over variables that it is difficult to generalize from case study results (Spencer & Dale 1979).

3.1.1.5 Theorem proof

This category of research is concerned typically with the technical aspects of IS (technology and computing) and is of considerably less use for research questions that address organizational and social aspects of IS.

3.1.1.6 Forecasting and futures research

Forecasting is a scientific method that uses techniques such as regression analysis and time-series analysis; this approach depends on the quality of historic data and the assumption of continuity. Futures research is interpretivist and particularly useful for investigating societal impacts of IT and can be used within organizations to create different scenarios of the future. The usefulness of futures research depends largely on the ability of those involved in building scenarios.

3.1.1.7 Simulation & game/role playing

Dickson et al. (1977) included simulation under laboratory experiments, while Jenkins (1985) has made a separate category. Simulation can be used to model the behaviour of a real-world phenomenon, allowing predictions about real-world behaviour to be made. Role playing is an interpretivist technique that uses people, rather than models, in role playing.

3.1.2 Interpretivist approaches to IS research

3.1.2.1 Argumentation

This approach is less structured than futures research and role playing and allows for creative thinking that may lead to novel ideas that can be tested and developed using more formal methods subsequently. The major perceived weakness of this method is its (potentially extreme) subjectivity.

3.1.2.2 Action research

In this approach the researcher is an active participant in an organizational situation, working towards practical outcomes (Clark 1972; Susman 1983). The richness of experience gained through this research is a major strength, while the potential ethical issues that can arise and the difficulties of interpretation are weaknesses.

3.1.2.3 Descriptive/interpretive research

Based upon the phenomenological tradition this method allows the researcher to continually question the biases and assumptions made when describing a situation. The skill of the researcher is a major factor in producing insightful and useful descriptions.

3.2 An IS research framework for the organizational laboratory

3.2.1 The organization as laboratory

A result of the binary distinction between scientific and interpretivist approaches is that IS research methods are categorized *either* as scientific *or* as interpretivist. As can be seen in the brief descriptions of the research methods in table 3.1 the desire to place each method in one camp or another does not always result in a clear-cut decision, as is the case with forecasting/futures research. Surveys and structured interviews can produce quantitative and qualitative data and can be subjected to scientific testing, to interpretation, or to both. A further issue is that the classification is divisive insofar as supporters of scientific approaches to research can reject interpretivist methods as lacking rigour and generalizability, while supporters of interpretivist approaches can attack scientific methods as being inappropriate and impoverished ways of enquiring into human systems (scientism is the application of scientific method to unsuitable topics).

Perhaps a more interesting categorization is between in-context approaches, such as case study, and artificial approaches, such as theorem proof and laboratory experiments. In support of this categorization, this author suggests that a distinctive feature of Information System research is a concern with the organizational context in which technical artefacts are developed and deployed. Weick (1984) argues that the appropriate location for IS research is the middle of the Douglas (1976) continuum of methods, which range from unconscious dreams through field research to mathematical models. In the computer science tradition of research a specific context of use is largely absent (Ehn et al. (1995) argue that the out-of-context evaluation of the quality of IT is a major source of problems of usability). The management and organizational behaviour research traditions do retain a richness of organizational context, but the technical aspects of computer systems development are pushed into the background and often disappear altogether (Button 1993). A major strength of IS research is the potential to maintain a view of organization and technical artefact, particularly through conducting IS research in specific organizational contexts.

This author would go further and suggest that the *primary* laboratory for the IS researcher is the organization, in which specific contexts of development and use of technical artefacts can be investigated. Certainly, with respect to the research theme of this thesis, which is concerned with a customer and use focus on IS quality it is difficult to see how the research could usefully be conducted in an artificial, out-of-context setting. However, that still leaves a range of in-context research approaches that could be used in this research.

Research carried out within organizations has a potential for the researcher to affect the research situation, inasmuch as all research conducted in the organizational laboratory is, to a greater or a lesser extent, an intervention. The role of intervention is viewed differently by the scientific and interpretivist traditions. With the scientific approach the researcher is an observer of the laboratory. Any intervention is strictly controlled such that only the experimental variable changes; the organizational context is kept constant in order to provide replicability and predictive power. When an interpretivist approach, such as case study, is used, researchers also attempt to minimize their impact on the situation, while recognizing that they are inescapably bound up in the laboratory. In both scientific and interpretivist approaches the researcher is making an intervention (in this author's opinion observation/interpretation constitutes an intervention) and can therefore affect the organizational context insofar as there will be unintended consequences of purposeful human activity (Giddens 1984). In some forms of interpretivist research method, such as action research, the aim is to gain knowledge through making deliberate interventions in the organizational setting.

3.2.2 Knowledge interests and IS research

Habermas (1972), as described by Dahlbom & Mathiassen (1993) and Flood & Jackson (1991) claims that research is motivated by interests and values. Habermas identifies technical, understanding, and emancipatory knowledge interests. The technical interest is concerned with explanation, prediction and control; only when the world is regular can one achieve control and repeatability. The interest of understanding is concerned with interpretation of data and history. The emancipatory interest is concerned with criticism as a basis for change and is founded on the view that power is distributed unequally. The intervention aspect of IS research referred to in the previous section can, directly or indirectly, contribute towards increasing oppression and thus the emancipatory knowledge interest introduces an ethical and critical dimension to IS research. In the Scandinavian tradition of IS research the need for researchers to be aware of critical aspects is well-established. Bansler (1989) reports on this critical tradition, which includes the work of Nygaard & Bergo (1975) with the Norwegian unions and the UTOPIA project in Sweden (Bodker et al., 1987). Ehn & Kyng (1987) recognize that IS research is not value-free and that conflict between different interest groups is endemic rather than exceptional. Muller (1995) considers the role of ethnocriticism for Human Computer Interaction (HCI) by drawing an analogy between anthropologists and HCI designers.

3.2.3 An IS research framework

Ngwenyama (1991) notes that the aim of critical theory is to 'integrate the three knowledge interests into a holistic approach to enquiry and intervention' (p. 271) and that theory and practice are related through an inquiry-change cycle. The research framework in figure 3.3 will be used to represent graphically individual and holistic views of the knowledge interests, and to assist in explaining the gap between (research) theory and (research) practice. The author recognizes that the research framework presented in this section is to an extent speculative and that there are strong counter-arguments for pure research methods that represent the separated interests of science and society.

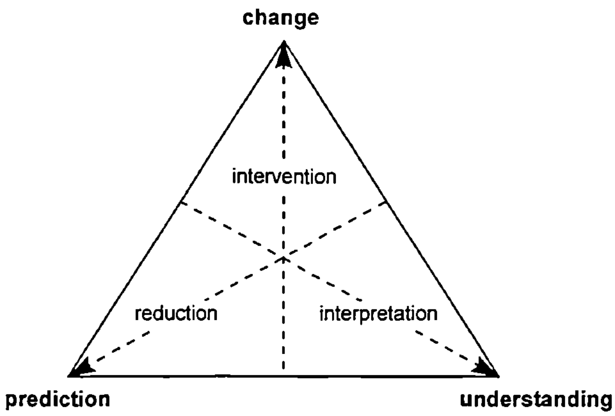


Figure 3.3: an IS research framework

The framework is a triangle comprising points, sides, and a constrained space. The points represent intended research outcomes and are aligned with the knowledge interests of Habermas: *prediction* with a technical knowledge interest (the scientific approach); *understanding* with an understanding interest (the interpretive approach); and *change* with an emancipatory interest (the critical approach). The points of the triangle should be viewed as ideal types in the Weberian sense, that is, they are non-moral abstractions that can be used to make comparisons with empirical reality. As such, these ideal type approaches to research are not attainable in practice, which is represented by the constrained space of the triangle.

The dotted lines inside the triangle represent movements towards the ideal types. As the researcher moves towards the prediction point through a process of *reduction* there should be greater explanatory power, predictive power, and statistical generalizability. Movement toward the understanding point through a process of *interpretation* is associated with greater in-context understanding of IS in the organizational laboratory. Movement toward the change point is achieved through a process of *intervention*, the results of which should be evaluated from an emancipatory viewpoint. The sides of the triangle represent trade-offs between the ideal types of research outcome:

- *understanding/prediction:* this side highlights the trade-off between a desire to make rich interpretations of complex situations (understanding) and the need to reduce complexity in order to ascribe cause and effect relationships (prediction). There is an intersection with the dotted line taken from the change point, which means that research located on this line will have no interventionary element and hence, as ideal types, will not result directly in change to the organizational context. In the case of prediction, the researcher is a detached observer of an organizational reality; in the case of understanding, the researcher is making an interpretation of a situation;
- *change/prediction:* a trade-off between making an intervention in the situation (change) and a desire to reduce the number of experimental variables in the interests of predictive power (prediction). On this side understanding is absent - in its pure form prediction is an instrument that requires no understanding for it to work, and change represents acts performed as an end in themselves (using the ideas of Schön (1983), this is the unreflective practitioner), as distinct from poiesis in which activity is carried out in pursuit of some ends;
- *understanding/change:* a trade-off between being an outside observer who can make interpretations (understanding) and a researcher involved in unreflective practice (change). On this side there is an absence of predictive ability; neither change nor understanding in their pure forms lead directly to predictive power.

It is not possible for a researcher to be involved with IS practice as though she/he were entirely and indistinguishably part of the organization, while also being an outsider who can stand back from the situation and make interpretations, and at the same time produce rigorous results in the reductive scientific tradition. Increasing the proportion of one ideal type is counter-balanced by a diminution of one or both of the other ideal types. Practice will be situated in the research space and be constituted of a mix of reduction, interpretation, and intervention. This space will be used to locate both IS research methods and IS research practice carried out in an organizational laboratory. In the next section, those IS research methods that support investigations in an organizational laboratory are reviewed and positioned within the research framework.

3.3 Research methods for the organizational laboratory

In this section the three main types of research method that are applied in the organizational laboratory are described: case study, action research, and field experiment. This author considers techniques such as surveys and interviews to be orthogonal to these methods since they might be used to a greater or lesser extent in all three types of research. Similarly, aspects such as duration (for example, longitudinal studies) are considered to be issues common to all three categories of research.

3.3.1 Case study

Visala (1993) notes that the case study has been classified as a scientific method by Galliers (1992), who followed the case study tradition of Lee (1989), while Iivari (1991) categorizes the case study as an idiographic, or interpretivist, method. In a revised taxonomy of IS research approaches, Galliers (1993) presents the various approaches as ranging from traditional positivist (observation-based) to newer post-positivist (interpretations) and positions the case study nearer to the observation-based end of the range. For the purpose of providing a contrast we can distinguish between the positivist *hard* case study and the interpretivist *soft* case study.

3.3.1.1 Hard case study

An example of the case study method that supports a hard approach is the model proposed by Yin:

> A case study is an empirical inquiry that
>
> - investigates a contemporary phenomenon within its real-life context, especially when
> - the boundaries between phenomenon and context are not clearly evident.
>
> In other words, you would use the case study method because you deliberately wanted to cover contextual conditions - believing that they might be highly pertinent to your phenomenon of study. (Yin 1994, p. 13)

Yin (ibid.) notes that case studies can be used in three modes: explanatory, descriptive, and exploratory. Case studies are applicable where the research question is of a "how" or "why" nature, where control over behavioural events is not needed, and where there is a focus on contemporary events. Case studies allow reality to be captured in detail and many variables to be analyzed; problems with case studies include the difficulty of generalization, lack of control over variables, and different interpretations by different stakeholders (Galliers 1992).

3.3.1.2 Soft case study

Galliers (1993) classifies 'descriptive/interpretive' research methods as strongly post-positivistic and Walsham (1993) describes an interpretivist (soft) approach to case study in which he argues that:

> However, from an interpretive position, the validity of an extrapolation from an individual case or cases depends not on the representativeness of such cases in a statistical sense, but on the plausibility and cogency of the logical reasoning used in describing the results from the cases, and in drawing conclusions from them. (p. 15)

The interpretivist approach is concerned with gaining understanding; generalization is the movement from a concrete situation to the social totality beyond the individual case (Orlikowski and Baroudi 1989 [quoted by Walsham 1993], Walsham 1995). Walsham declares a topic of interest and overall premise and uses these to choose appropriate methodologies and methods (Walsham 1993, p. 22). Case studies will often be carried out longitudinally (Pettigrew 1990), thus providing the opportunity to observe the unfolding of events over time. A longitudinal approach is often supplemented by detailed historical reconstruction of earlier periods.

3.3.2 Action research

The roots of action research can be traced through that part of research that has been taken up with democratization and organizational development. There is a link from Lewin's (1948) research on social change and social conflicts, through the Tavistock Institute's work on socio-technical theory (Emery & Trist 1960), to Checkland's view of human activity systems (Checkland used action research to develop the soft systems methodology and uses action research when applying the soft systems methodology). There are no tight definitions or agreed principles of action research, although *action research* (Argyris & Schön 1991) and *participatory action research* (Whyte 1991) are two discernible traditions in the broader category of participatory ethnography (Thomas 1993).

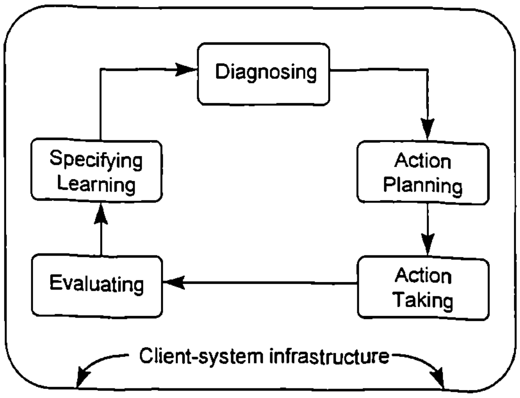


Figure 3.4: action research (Susman 1983)

Mingers (1984) identified four approaches to action research: phenomenology, ethnomethodology, language, and hermeneutics. These different schools of thought are useful for thinking about action research. For example, an ethnomethodologically informed approach would be suspicious of a strong use of theory in the first instance, preferring for the theory to come out of the data collection and analysis, as is the case with grounded theory (Glaser & Stauss 1967, Strauss & Corbin 1990). This approach can be contrasted with the action research of Susman & Evered (1978) and Checkland (1991) in which the researcher declares a theoretical framework in advance of entering a problem situation.

Action research has been typified as a way of building theory and descriptions within the context of practice itself. The theories are tested through intervention in the organizational laboratory, that is, through experiments that bear the double burden of testing hypotheses and effecting some desirable change in the situation (Argyris & Schön 1991). A model for action research that has been adopted widely is from Susman & Evered (1978) and Susman (1983). This approach first requires the establishment of a relationship between researchers and the participants' (clients') infrastructure. The action research cycle consists of five phases: diagnosing; action planning; action taking; evaluating; and specifying learning (figure 3.4).

In a response to Jonsson (1991), Checkland (1991) holds that a methodological framework for action research must be declared explicitly in the interests of rigour and 'making such results coherent and potentially transferable' (p. 402). Checkland describes a generic model that is applicable to any piece of research. This model contains a framework of ideas (F), a methodology (M) and an area of application (A) (figure 3.5).

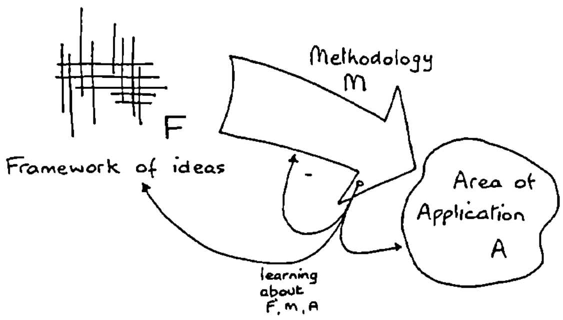


Figure 3.5: a generic model for research (Checkland 1991)

The methodology is used to mediate between the framework of ideas and the problem situation, with learning outcomes being achieved in terms of F and/or M, and/or A. The generic model of action research (figure 3.5) is implemented in action research through cycles of intervention (figure 3.6). The process of action research is shown in a seven-stage model in figure 3.7. There are clear parallels between the seven-stage model of Checkland and the five-step model of Susman. For example, the action planning stage of the Susman model is concerned with the identification of planned actions guided by a theoretical framework.

Checkland sees the declaration of an explicit methodological framework as a vehicle for establishing the validity of action research, 'thus beginning the process of developing a legitimate rigorous alternative to positivistic research' (Checkland

1991, p.402). Checkland (1991, p. 402) comments that Jonsson (1991) meets some of the needs of the seven-stage model, such as a careful negotiation of the role of the researcher and 'a relatively modest aspiration on the part of the researchers as to what action research can achieve', but concludes that an explicit methodological framework is needed to make the results of action research 'coherent and potentially transferable'. Also, the declaration of a framework of ideas and methodology are important if action research is to be distinguished from consultancy (Baskerville & Wood-Harper 1992).

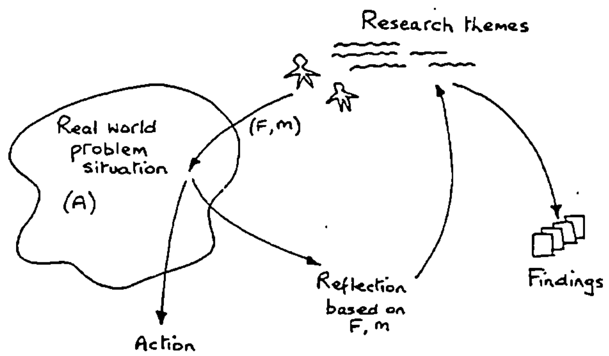


Figure 3.6: action research (Checkland 1991)

Participatory action research is a form of action research that involves practitioners as both subjects and co-researchers. Whyte (1991) defines participatory action research (PAR) as a process in which some of the people in the organization or community being studied actively participate with the professional researcher throughout the research process from the initial design to the final presentation of results and discussion of the action implications.

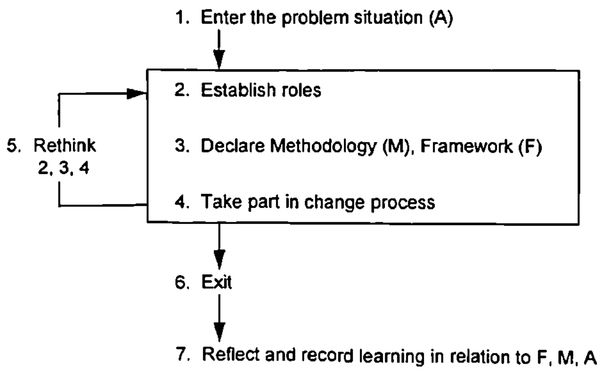


Figure 3.7: action research (Checkland 1991)

3.3.2.1 Critical approaches to action research

It is, of course, possible for a researcher to make an intervention without taking a critical perspective. For example, the aim might be to test and develop further a new system development technique or a new CASE (computer-aided systems engineering) tool. An intervention is made and change occurs, but assessment of the research might be made in functionalist terms, such as reduction in development life-cycle time or cost-savings. Not surprisingly, action research and participatory action research have been criticized for perpetuating the prevailing power structures and systems of control. According to Thomas (1993, p.3), 'critical ethnographers describe, analyze, and open to scrutiny otherwise hidden agendas, power centers, and assumptions that inhibit, repress, and constrain'. Thomas (ibid.) defines emancipation as the separation of constraining modes of thinking or acting that limit alternative possibilities - repression occurs where thought and action are constrained such that recognition of the alternatives is not possible.

3.3.3 Field experiment

Field experiments are an extension of laboratory experiments into the real world of organizational context. One feature of the laboratory experiment that is applicable to field experiments is the identification of precise relationships between chosen variables using quantitative analytical techniques. This is less rigorous than a laboratory experiment as there are lots of factors which the researcher cannot control but which could affect the outcomes. With a view to making generalizable statements which are applicable to real-life situations, the motivation for field experiments is to construct an experiment in a more realistic environment than is possible in a laboratory setting.

Two essential elements of any experimental design are randomization and experimental control (Zmud et al. 1989). Randomization involves allocating the people or units being studied to the experimental group, or to a control group, on an entirely random basis, taking no account of their characteristics or preferences. Experimental control is essential and involves taking appropriate steps to eliminate "nuisance" variables, which are factors other than the independent variables that might be responsible for observed changes in the dependent variable. There are two types of field experiments (Cook & Campbell 1979, Zmud et al. 1989): "true" experimental design which meets the criteria of multiple treatments (or one treatment and a control group), randomization, and experimental control; and "quasi" experimental design, which does not meet these three criteria but rather attempts to preserve as many of the properties of true experimentation as possible, given the constraints of the research setting.

Field experiments aim at controlling a small number of variables which may then be studied intensively. A major advantage is that the experiment is conducted in a real-life setting. A major problem however is the difficulty of finding organizations prepared to be experimented on. In addition, replication is problematic, in the sense that it is extremely difficult to achieve sufficient control to enable replication of the experiment with only the study variables being altered. The difficulty of conducting true experiments in an organizational laboratory is reflected in a survey conducted by Zmud et al. (1989) of the use of field experimentation within IS research in which they found only seven such studies reported.

The framework developed in the next section reflects the current author's concern with the separation of scientific and interpretivist approaches to research, and the gap between theory and practice.

3.4 Comparison of in-context IS research methods

In broad terms action research is aligned with change, case study with understanding, and field experiment with prediction in order to locate the research methods described in this section in the research framework (figure 3.8). Hard case study and quasi-field experiment have a less pure basis with respect to the ideal types of research outcome and are placed in the triangle such that hard case study is represented as a mix of understanding and prediction and quasi-field experiment as a mix of prediction and change.

3.4.1 The role of intervention

A major differentiator between the research methods is the role of intervention. Case study methods attempt to minimize changes caused by the research activity. In action research the aim is to support desired change in an organizational setting, while field experiments are geared towards hypothesis testing and a desire to keep the organizational context constant. In action research the aim is to build/design a future by pursuing change, while the case study often has a more historic perspective, looking to the past in an attempt to understand why certain things happened, taking account of the immediate research domain and the more general context. Field experiments aim at controlling variables in order to learn in general and to be able to predict the future. The experimental nature of the changes is in real-time, but often artificial given the constraint of hypothesis testing.

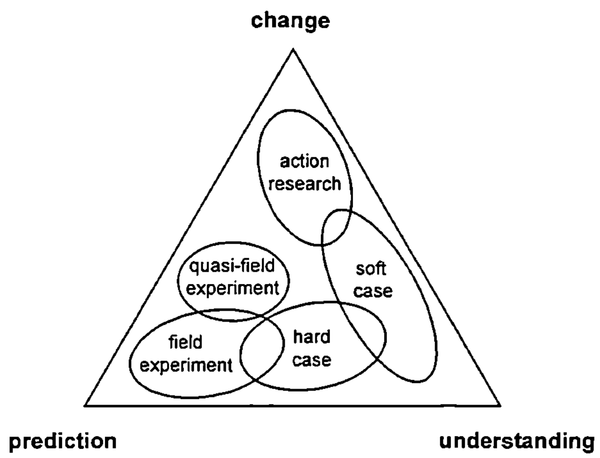


Figure 3.8: positioning of traditional forms of IS research into the framework

The main argument for case study as part of the scientific tradition is that the researcher observes facts (rather than interprets) and does not intervene in the situation being observed. However, Yin (1994) includes the following sources of case study evidence: documentation, archival records, interviews, direct observations, participant-observation, and physical artefacts. The current author argues that interviewing and observation are not neutral. Questioning of interviewees might lead them to reflect upon their role in the organization, and when organizational actors are aware that they are being observed then there can be changes in behaviour (see the "Hawthorne Effect" as described in Schwartzman (1993)). The best the researcher can do in conducting a case study is to try to minimize the impact they have on the situation, to move away from the change point along the dotted line labelled intervention (figure 3.3) towards the prediction/understanding side of the framework.

3.4.2 Validity and generalizability

The issue of validity is of major consideration in the selection of research strategy (Benbasat 1989). According to this view research findings can be evaluated on two principal criteria: internal validity and external validity. The degree of internal validity is the degree of confidence with which it can be claimed that the independent variable really did cause the observed change in the dependent variable. Internal validity is assessed by considering factors other than the independent variable which could have caused the change in the dependent variable. The degree of external validity is the extent to which the findings from the research setting can be generalized to other settings. Research designs that are strong on internal validity tend to have poor external validity and vice versa. The ability to control variables in an experiment helps secure internal validity but the artificiality will be likely to limit external validity. The richness of case study research strengthens external validity but the lack of control over variables weakens the internal validity of such findings. The same applies to action research, but in addition the active role of the researcher will weaken the internal validity as well - did the skill or personality of the researcher cause the observed change in the dependent variable, or was the change due to an independent variable?

Walsham (1995) argues that the statistical generalizability of scientific method is complemented by four types of generalization in interpretive research: the development of concepts (e.g., Zuboff's (1988) concept of 'informate'); the generation of theory (e.g., Orlikowski & Robey's (1991) framework concerned with the organizational consequences of IT); the drawing of specific implications (e.g., Walsham & Waema (1994), who conducted an in-depth study of IS development in a financial services company over an eight-year period); and rich insight (e.g., Suchman's (1987) detailed analysis of a particular copying machine which can yield rich insight for the reader on a range of topics that go beyond the categories proposed by the author).

3.4.3 The role of theoretical research

The research framework described is restricted to research conducted in the organizational laboratory. A number of theoretical approaches to IS research were described in section 3.1, reflecting research work carried out away from the organizational laboratory. Latour (1987) talks about 'centres of calculation' and 'action at a distance'. Knowledge is concerned with bringing things back to the centre for someone to see it for the first time in order that others might be sent back to bring other things back with them. Bringing things back to the centre is not enough: 'a geologist surrounded by hundreds of crates full of unlabelled fossils is in no better position to dominate the earth than when he was in Patagonia or Chile' (Latour 1987, p. 233). Effort is needed at the centre to make inscriptions, not just first order but *n*th order and never-stopping, translating concrete theories into more abstract theories.

The problem is to keep informants by your side while they are far away. The organization cannot be brought to the IS research centre, but questionnaires and case studies case studies can be brought out of the organizational context and inscripted - the ticks on questionnaires can be totalled and analyzed, interviews can be transcribed and interpreted and the inscriptions used to act at a distance. Munro (1995) uses Latour's ideas to understand the role of accounting as a centre of calculation that can act at a distance. In terms of the research framework, the inscription of the research findings takes place outside of the triangle; researchers go away from the centre into the organizational context and return with more things that can be inscribed.

3.4.4 Comparison

The framework in figure 3.3 shows the outcomes change, prediction, and understanding together with the research approaches intervention, reduction, and interpretation respectively. These research outcomes are summarized in table 3.2 with respect to the research methods described in this section. In addition time-related characteristics have been included to provide a richer depiction of the research methods. The duration of the research could be a constraint in choosing a method; for example, action research is often conducted with projects of long duration (Jonsson 1991).

The messiness of carrying out research in an organizational laboratory means that it is often difficult to remain faithful to ideal type research methods. In the next section the IS research framework is used to aid the research design.

		research method				
		hard case study	soft case study	action research	field experiment	quasi-field experiment
research outcome	change (intervention)	unintended	unintended	potentially large intended change, but also unintended consequences	unintended	small intended change, but also unintended consequences
	prediction (reduction)	medium	low	low	high	medium
	understanding (interpretation)	medium	high	medium	low	medium
research characteristics	duration	any duration	any duration	long duration	short duration	medium duration
	time orientation	historic	historic	building future	real-time and future	real-time and future

Table 3.2: characteristics of IS research methods

3.5 Research design

According to Galliers (1992), the purpose of research is to make a contribution to knowledge. This seemingly straightforward assumption leads one into the difficult area of defining what knowledge is and what constitutes valid knowledge, especially in the light of the opposing views of positivism and interpretivism that have been discussed above. Galliers' (1992) taxonomy of IS research methods identifies the following epistemological objectives: theory building; theory testing; and theory extension (table 8.4, page 159). These research aims need to be related to research methods such that the researcher can achieve an appropriate fit between research question, research aim, and research method. The initial choice of method is likely to result in a strong form of one of the research methods shown in table 3.2, or perhaps a combination of methods (Gable (1992) argues for multi-method design and promotes the benefits of integrating case study with quantitative survey methods; Lee (1991) considers the integration of positivist and interpretivist research approaches).

The research theme outlined in chapter 1 is of a general nature and potentially covers a wide range of IS research issues. The research theme emphasises understanding:

The adoption of a quality approach to information systems development will contribute to the delivery of successful information systems

The theme has a practical interest reflected in the author's desire to explore IS development and quality management jointly through the development of an ISDM/Q, a theory that can be tested. Case study and action research are appropriate to building and testing theory. Checkland's (1991) action research model (figures 3.5, 3.6) requires that a methodology and a framework of ideas be declared in advance of an intervention taking place. If a framework of ideas is to be established then some preliminary work will be needed before action research can be embarked upon: the framework of ideas might be adopted from previous research, from extensions to previous research, or generated afresh.

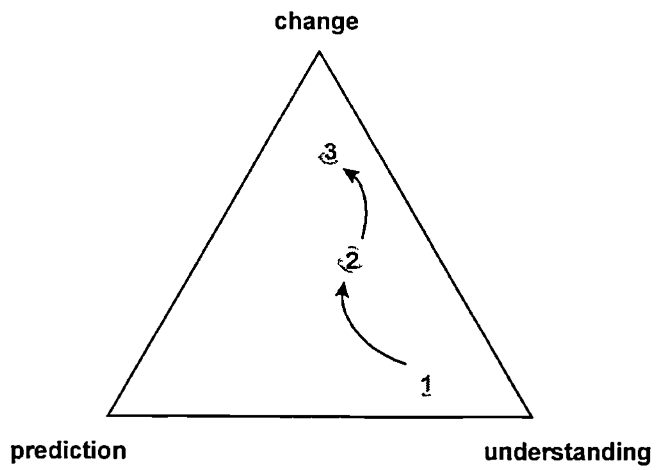


Figure 3.9: phases of the fieldwork (proposed)

This research is based upon a framework of ideas (chapter 4), F, that develops from and extends the literature review (chapter 2). To learn about the area of application, A, phase 1 of the fieldwork consists of a series of interviews (point 1 in figure 3.9). The understanding of (A) gained in phase 1 is used to guide the selection of two small-scale case studies, which also have a limited element of intervention, in phase 2 of the fieldwork (point 2 in figure 3.9). The case studies, together with the framework of ideas developed in chapter 4, are used to develop a methodology (chapter 5) that can be made operational and then used to guide the intervention carried out via action research (point 3 in figure 3.9) in phase 3 (chapter 6) of the fieldwork.

The research framework shows a movement from understanding gained through interpretation to change made through intervention. In chapter 8 the actual research is contrasted with the planned research and a reconciliation made. Also, the research must be reflected upon in order to record the learning that arises with respect to the methodology (M) and the situation of concern (A) (chapter 7) and the framework of ideas (F) (chapter 8). The planned fieldwork phases are summarized in table 3.3.

Phase	Description
1	Literature survey and interviews of system development personnel in order to gain understanding of the area of application (A) and to develop the framework of ideas (F)
2	Case studies of implemented computer systems to gain understanding of IS quality issues and to build a methodology for intervention (M) within the framework (F)
3	Action research to apply the operational methodology in an organizational context in order to learn about M, F, and A.

Table 3.3: planned phases for the fieldwork

Chapter summary

In this chapter research methods were categorized according to the scientific/interpretivist distinction and a range of methods appropriate to IS research described. A distinction between in-context and out-of-context approaches to IS research was proposed. IS research methods and IS research practice were described using a framework in which the outcomes change, understanding, and prediction are matched with the processes of intervention, interpretation, and reduction respectively. The research theme introduced in chapter 1 was considered to be suitable to a treatment that focuses on interpretation and intervention, leading to a research model that incorporates three phases of fieldwork: preliminary investigation, case study with a small element of intervention, and action research. The model adopted for guiding the action research is Checkland's (1991) seven stage process. The actual research will be reconciled with the planned research in chapter 8 using the research plan of figure 3.9.

4

A multiple perspective framework for IS quality

Introduction

In chapter 1 the International Standards Organization (ISO) definition was recognized as a widely accepted notion of quality and adopted in this research as a starting point for an investigation into IS quality. In chapter 2 different approaches and traditions in IS and software quality were surveyed with the aim of placing this thesis in the context of prior research. In chapter 3 the research approach was selected. The literature review showed that a considerable range of activities are legitimated through an appeal to quality, although many of these activities are only indirectly associated with customers and customer satisfaction (such as the capability maturity model approach to software development). Rather than face the difficult and messy problem of customers, developers often take refuge in a world of technical rationality that privileges science and technology. Although quality might be a largely totemic notion it serves as a legitimating device for significant business decisions and it is therefore important that the implications for IS development of different (and possibly conflicting) notions of quality are explored.

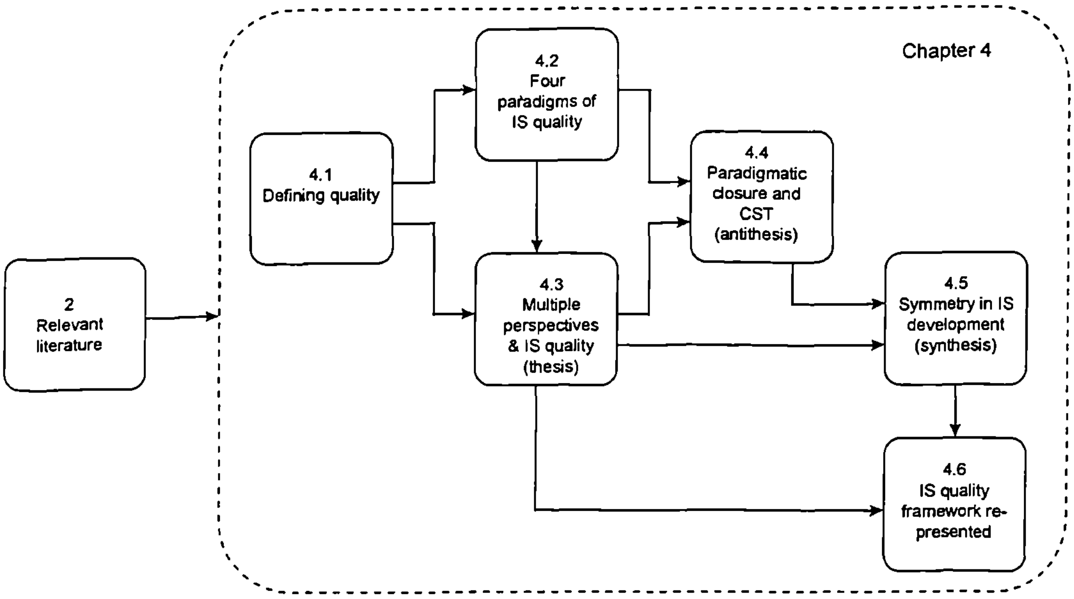


Figure 4.1: structure of chapter 4

In this chapter, the notion "quality" is investigated in greater depth in order to provide a framework of ideas that will inform the IS quality methodology developed in chapter 5 and utilized in chapter 6. The structure of the chapter is as follows (figure 4.1). Firstly, definitions of quality are explored using Garvin's (1984) five views of quality and the "voice of the customer" stance advocated generally in total quality management (TQM) and more specifically in quality function deployment (QFD). A synthesis is made leading to a generalized quality model, which is then analyzed in the second section using the four paradigm framework of Burrell & Morgan (1979). The third section introduces a multiple perspective framework for IS quality (this is the thesis of the chapter) and the primary methods for analysis of the organizaton's quality requirements, viz. Soft Systems Methodology (SSM) and Strategic Assumption Surfacing and Testing (SAST) are described. In the fourth section the issues of paradigmatic closure and a critical perspective on IS development and IS quality are considered (this section represents an antithesis). In the fifth section symmetrical approaches are used to understand the process of IS development, particularly structuration theory (Giddens 1984) and actor network theory (Latour 1987). In the last section the generic IS quality framework proposed in section 4.3 is re-presented in the light of a symmetrical approach to object and subject worlds. The major inter-dependencies between the sections and the flow of the argument are shown in figure 4.1.

4.1 Defining quality

Garvin (1984) identified five views of quality: product-based; user-based; manufacturing-based; value-based; and transcendent. These views of quality provide a useful starting point for a discussion of the notion "quality". With the *product*-based view it is assumed that quality is an attribute of a product in which 'differences in quality amount to differences in the quantity of some desired ingredient or attributes' (Abbott 1955). A *manufacturing*-based view of quality is concerned with producing products that conform to a specification in which 'quality means conformance to requirements' (Crosby 1979). The *value*-based view introduces an economic constraint to product quality, recognizing that an idealized product is not necessarily a quality product: 'quality is the degree of excellence at an acceptable price and the control of variability at an acceptable cost' (Broh 1982). The value-based view of quality highlights that there are constraints on the production of quality products; in this case it is an economic constraint, but it is possible to think of further constraints, such as law and ethics

A *transcendent* view considers quality to be something that cannot be articulated; we know a quality product when we see it but find it hard to pinpoint particular characteristics that make it a quality product:

> Quality is neither mind nor matter but a third entity independent of the two.......even though quality cannot be defined, you know what it is. (Pirsig 1974)

The transcendent view of quality is concerned with quality aesthetics and can be likened to primitive Platonic concepts such as "beauty" and "truth"; by being exposed to a succession of quality objects we develop a sensitivity for quality.

The *user*-based view of quality is concerned with meeting the expectations of the customer. This view of quality has been given considerable emphasis in the quality literature and has played a major role in the development of TQM. Juran

(1979) holds that 'quality is fitness for use', a definition that is followed chronologically by Feigenbaum's (1983) view of quality as:

> The total composite product or service characteristics of marketing, engineering, manufacture, and maintenance through which the product and service **in use** will meet the expectation of the customer. (current author's emphasis)

The International Standards Organization (ISO8042 1986) have adopted a user-based definition of quality:

> The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.

A more explicit definition of user-based quality, which is also more positive in terms of surpassing rather than satisfying needs is (Gitlow et al. 1989):

> Quality is a judgement by customers or users of a product or service; it is the extent to which the customers or users believe the product or service surpasses their needs and expectations.

From a review of the quality and TQM literature it is evident that the user-based view of quality has achieved a dominance. This does not mean that the other views of quality identified by Garvin are irrelevant or insignificant; TQM, as described in chapter 2, emphasises the need for a quality culture to permeate all the activities of an organization, including the adoption of a customer/supplier metaphor for internal "markets", and Deming's three cornered view of quality described in chapter 1 incorporates product, service, and use views of quality. Garvin (1984) comments that:

> These examples suggest the need to actively shift one's approach to quality as products move from design to market. The characteristics that connote quality must first be identified through market research (a user-based approach to quality); these characteristics must then be translated into identifiable product attributes (a product-based approach to quality); and the manufacturing process must then be organized to ensure that products are made precisely to those specifications (a manufacturing-based approach to quality). (p. 29)

This is the approach adopted in Quality Function Deployment (QFD) in which qualities demanded by customers are deployed into product quality characteristics that can be managed by the supplier, with further deployments into product functions, product parts and manufacturing (figure 4.2).

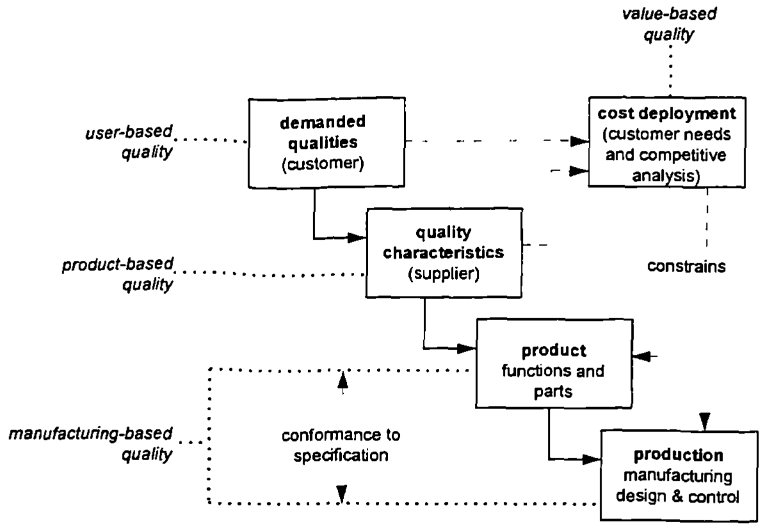


Figure 4.2: a synthesis of Garvin's views of quality with QFD

In QFD terminology this should not be seen as a 'shift of one's approach' (Garvin 1984) but as the logical result of carrying the "voice of the customer" through the entire design and manufacture process. In the context of a physical product, in this case a pencil, the following might be relevant (King 1989):

- a *demanded quality* of a pencil might be "does not smear";
- *quality characteristics* associated with the demanded quality are "time between sharpening" and "lead dust generated";
- *functions* of the pencil include "write" and "erase";
- *parts* of the pencil include "lead", "eraser", "wood".

Cohen (1995) gives an example of QFD for software:

- a *demanded quality* is "know what an icon is going to do before it is clicked";
- a *quality characteristic* relevant to this customer need might be "percent of correct identifications of icon meanings by users in a panel test" together with some target, such as 96% recognition;
- *functions* associated with the characteristics might be "icon, when clicked, causes operation to be executed" and "icon, when cursor passes over it, causes explanatory message to be displayed".

The focus on customers and their needs expressed in terms of benefits differentiates a TQM approach to IS development from the traditional basis of structured development methods, which place an over-emphasis on the specification of functional requirements resulting in a statement of what the product does that has been separated from an understanding of why it might be useful to the customer. If this fundamental connection with customer demanded qualities is lost then it is difficult to see how a more mature software process or the introduction of a quality management system such as the ISO9000 series can do more than provide a second order quality improvement.

The approach in figure 4.2 shows demanded qualities being mapped into quality characteristics, which in turn are mapped into product functions. Cohen (1995) suggests that in some situations it is appropriate to miss out the quality characteristics stage and to map demanded qualities directly into product functions. One of the circumstances in which this might be reasonable is (Cohen 1995):

> The development team lacks either the time or the interest to develop and prioritize performance measures......
>
> In addition, some development teams, especially software development teams, are unaccustomed to using performance measures in their product definition process. For such teams, these measures only get in the way of what they see as their work. While translating customer needs directly into functions lowers the chances for breakthrough ideas, teams that don't normally use performance measures may be better doing just such a translation. (p. 131)

It is interesting that Cohen, a practitioner with a broad and general experience in the application of QFD, has made specific reference to software development as an example of a domain in which QFD techniques are difficult to apply, a difficulty which he ascribes to the software developer's primary concern with product functionality. This author would go further and argue that most software development projects do not address the analysis of demanded qualities in a rigorous and methodical manner and are therefore in no position to identify quality characteristics; certainly they are not in a position to make an in-context connection between qualities, characteristics, and functions. Where quality characteristics are considered by software developers then it is often with reference to global characteristics and global metrics rather than with in-context derived characteristics and specific metrics. Of course, it is possible that computer system development is different from other types of product and service development and one of the aims of this research is to propose reasons for the low rate of adoption of TQM techniques in IS and software development.

There are three issues that arise from analysis of TQM literature. The first is customer satisfaction, since this concept is central to the idea of a user-based view of quality. The second is cost, which is necessary if a value-based view of quality is to be integrated with a user-based view of quality, and the third is timeliness, an issue of some concern in IS development. Although these three issues reflect the TQM orthodoxy and are necessary for IS development, it will be shown later in this chapter that they are not sufficient.

4.1.1 Customer satisfaction

Customer satisfaction is used as a surrogate for quality in user-based approaches to quality management. The Kano model of customer satisfaction (figure 4.3) considers quality requirements in three ways: performance quality, basic quality, and excitement quality (Kano et al. 1984). *Performance* quality is one dimensional and concerned with spoken customer requirements that are documented in a functional specification - conformance to specification is an assessment of how well this type of requirement is met. It is one-dimensional in the sense that as stated customer requirements are met then customer satisfaction increases. *Basic* quality is concerned with requirements that are not stated but which the customer expects to be met. As with performance quality, if these requirements are not met then customer satisfaction will suffer. However, the converse is not true as meeting basic requirements will not improve customer satisfaction - these are expected qualities of the product. For example, one would expect a word-processor to be able to print a document and one would not expect to be electrocuted by one's personal computer - these are basic quality requirements. *Excitement* quality is concerned with attributes of a product which cannot be stated since the customer has not experienced them before. Excitement quality will not be a dissatisfier if it is absent but if excitement quality is achieved then customer satisfaction will increase. For example, a customer might not expect a word-processor to have an in-built facsimile facility, but may well be surprised and delighted to find that it has - this product feature might contribute to excitement quality. Customer satisfaction, according to the Kano model, is a function of these three types of quality (figure 4.3).

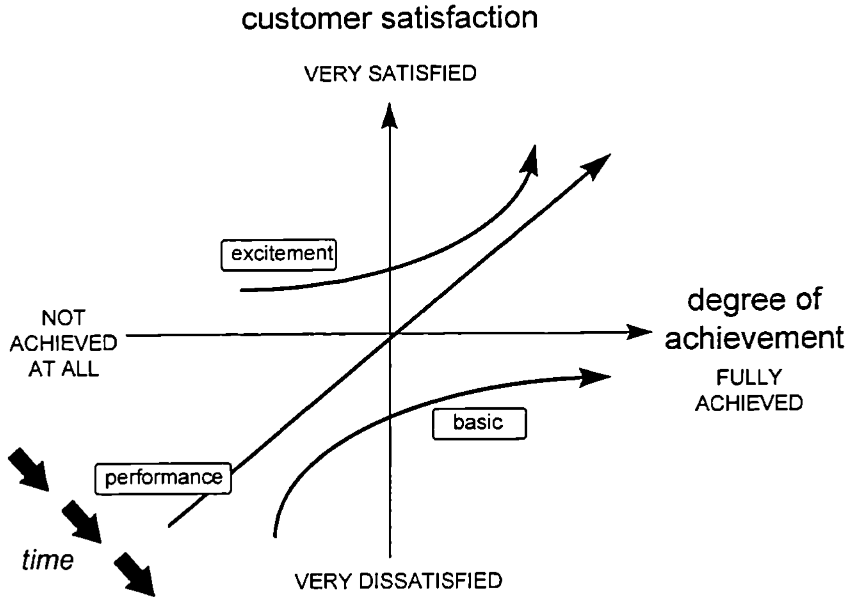


Figure 4.3: Kano model of quality types

Over time there is a drift towards basic quality as performance quality requirements become basic quality requirements and excitement qualities become common-place requirements. For example, having been surprised to find a facsimile facility on a word-processor (excitement) a customer might ask for it on their next word-processor (performance). If over time all software vendors incorporate facsimile facilities in their products in response to market demands, then the customer might assume that any word-processor would have this capability (basic). Should the customer assume this to be the case and purchase a word-processor that does not have this facility then customer satisfaction with this product is likely to suffer. The exciting quality has, over time, become a basic quality.

The ISO definition of quality includes the performance and basic quality categories through the satisfaction of 'stated or implied needs' (ISO8042 1986), but as it contains no allusion to excitement quality the ISO definition conveys a view of quality as providing just enough to satisfy customers. The definition of quality furnished by Gitlow et al. (1989) quoted above does talk about *surpassing* customer needs and expectations; given that quality is mobile, with quality requirements slipping from excitement to performance to basic over time, then it is important for organizations to consider excitement quality explicitly if they wish to attract and retain customers. The requirements engineering tradition in IS development seems to place an overdue emphasis on performance quality and the creation of an articulated specification. A risk of the specification-driven approach is that some aspect of basic quality might be overlooked, such as security, while excitement quality is ignored altogether.

4.1.2 Cost and timeliness

The customer satisfaction view of quality makes no mention of cost. This does not mean that customer needs should be satisfied regardless of cost. In QFD cost is treated as a constraint (figure 4.2); it is something to be approached in a way similar to the management of technical constraints. Consider the relationship between quality and cost as shown in figure 4.4. In the TQM orthodoxy it is argued that the likelihood of survival is increased for organizations that supply high quality products at low cost. A total approach to quality requires that all stages of the product development life-cycle be considered together, aiming for increases in quality (customer satisfaction), reductions in cost, and improvements in timeliness, which is represented by a movement toward the upper right hand quadrant of figure 4.4.

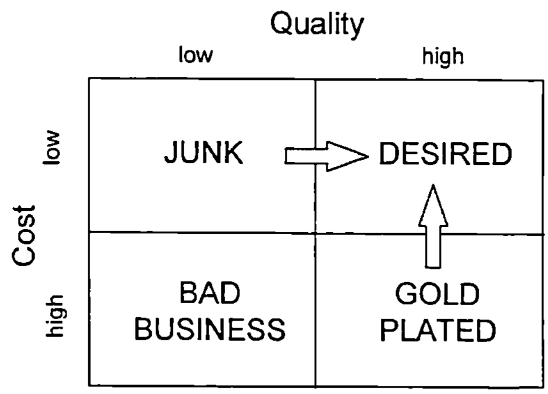


Figure 4.4: quality and cost

A predominant view in IS is to view the development process as a three-way trade-off between product capability, timeliness (business urgency), and cost. The QFD approach begins with customer requirements, the "voice of the customer", and then deploys them through all stages of product development. This view sees product functionality, cost and timeliness as issues to be traded-off with reference to customer demands. Where possible significant trade-offs should be mitigated or eliminated entirely through break-through analyses, which might include the introduction of new concepts, new methods and new tools. Where the trade-off has to be made it is done with reference to the qualities demanded and prioritized by the customer.

4.1.3 Summary

The Garvin and QFD models can be expressed as follows:

> *a subject perceives the quality (*user - *customer satisfaction) of an object (*product - *quality characteristics), which is produced by artificial means (*manufacturing - *conformance to specification) in a situation where one constraint, economics, has been privileged (*value - *acceptable cost, acceptable price).*

The above summary raises a number of issues:

- what is meant by "customer" and how are they identified?
- what constitutes quality for customers?
- what is the appropriate way to manufacture the product?
- is it acceptable to privilege cost (ethics)?
- who benefits from the quality improvement (power)?

In the next section the simplified view of quality expressed above is subjected to a deeper analysis through the application of different paradigms.

4.2 Four paradigms of IS quality

In this section the four paradigm model of Burrell & Morgan (1979) is used to explore different assumptions that might inform the approach taken to IS development and the conceptualization of quality. In theory these assumptions should have a major influence on the content and application of an IS development method and thus have significant implications for the definition and assessment of IS quality.

The four paradigm model proposed by Burrell & Morgan (1979) is well-established, having been applied in IS research by Klein & Hirschheim (1987), Hirschheim & Klein (1989), and Avison & Wood-Harper (1990). The framework involves the categorization of assumptions on objectivist/subjectivist and regulation/radical change dimensions (figure 4.5).

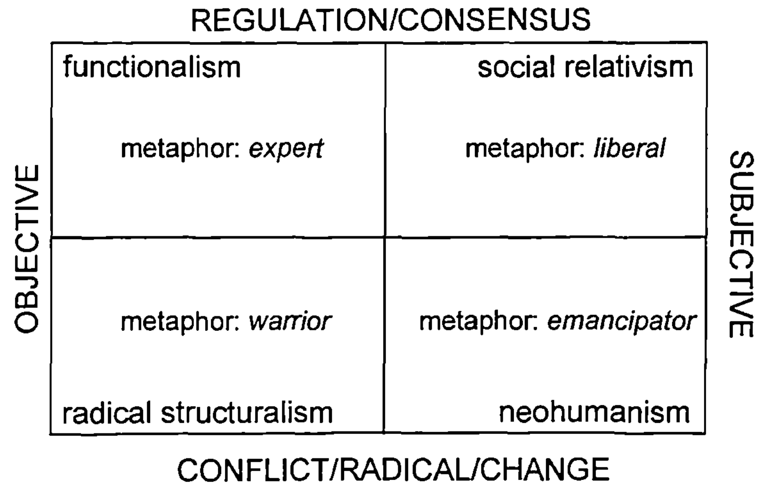


Figure 4.5: four paradigms for IS quality (adapted and merged from Hirschheim & Klein, 1989, and Avison & Wood-Harper, 1990)

The objectivist position is characterized by a realist ontology and a positivist epistemology. Loosely speaking this means that the world is assumed to be objectively given, that is, objects and structures exist as empirical entities independent of human observers. The appropriate way of acquiring knowledge of the world is to apply nomothetic methods, which is the study or discovery of general scientific laws using the techniques of observation and the identification of causal relationships (correspondence to reality is a measure of a good theory). The subjectivist position holds that different people interpret the world in different ways and that scientific method is not appropriate for the study of social organizations; human beings have free-will (their behaviour is voluntaristic rather than deterministic). According to the subjectivist, idiographic methods are needed to acquire knowledge.

The regulative view of the world sees order, stability, and integration; the radical change view of the world sees conflict, coercion, and disintegration. These two classifications yield four combinations: functionalism (objectivism/regulation); radical structuralism (objectivism/radical change); social relativism (subjectivism/regulation); and neohumanism (subjectivism/conflict). In figure 4.5, these positions have been represented by the metaphors of expert, warrior, liberal, and emancipator respectively (Avison & Wood-Harper 1990). These paradigmatic metaphors are used in the following sub-sections to explore different approaches to IS development and different conceptualisations of IS quality.

4.2.1 Functionalism - the expert

The *expert* considers that customer quality requirements as having a real-world existence; these requirements need to be captured and related to quality characteristics of particular products and services. The relationship between the qualities demanded by customers and product characteristics can be modelled using formal and mathematical techniques. IS development methods should focus on capturing the underlying, real, true requirements of customers. Such methods will tend to adopt an engineering-based approach since it is believed that requirements can be elicited and an appropriate product designed and manufactured. IS developers as experts see themselves as philosopher-kings 'far removed from the subjective squalor of organisational politics (Knights & Murray 1994, p. 89). For example, Zahedi's (1995) approach to IS quality espouses a strongly functionalist approach:

> Knowing what you want or need seems obvious. But in many business - and even personal - decisions, the **discovery** of **exactly** what you need requires a careful analysis and formal process. Although people normally live and sometimes adjust to choices that do not reflect their **true** needs, **errors** in identifying the **true** needs of customers could prove to be very **costly** for business. Since products such as information-systems services are thoroughly defined by whether they address a **real** need, the elicitation of the needs of information-systems customers **determines** the success or failure of the system. (page 156) (current author's emphasis)

The functionalist approach typically recognizes few groups of customers and will privilege those who use the product directly or those with a financial stake, such as the purchaser of the product. Multiple customers might be identified through the external entities and user roles identified from data flow diagrams (Kotonya & Sommerville 1992), but such an approach focuses on those potential customers who are affected by formal flows of data. With respect to regulation, where different groups have differing quality requirements there is a belief that any conflict between requirements can be resolved. Typically there is a preoccupation with mechanistic measures of efficiency and an overriding concern for cost in which political issues are just an irritation getting in the way of the real work of verifying and validating customers' needs (Zahedi 1995):

> The *verification* of customer needs involves making sure that the customer's statements are correctly communicated and interpreted. The *validation* of customer needs assures system designers that customers' stated preferences reflect their true needs and wishes, and are not motivated by political, spur-of-the-moment, or other spurious factors. (original emphasis) (p. 157)

Zahedi's view of politics can be contrasted with Knights & Murray (1994) who 'identified organisational politics as the motor of organisational life' (p. 245). The idea of IS development as a value-free exercise is mirrored in business process reengineering (Krass 1991 quoted by Teng et al. 1992):

> Ford Motor Company, Mutual Benefit Life Insurance, AT&T, and DEC report increases in productivity and decreases in staff by about 80 percent after business reengineering (Krass 1991). DEC was able to consolidate 55 accounting groups into five and was able to **eliminate** 450 jobs. (current author's emphasis)

There is no mention of values or ethics in the paper by Teng: the implicit assumption is that the goal is to improve performativity and, as less people equals less cost, then the elimination of staff is "good". Clearly, although powerful and deeply entrenched, the functionalist approach is narrow and mechanistic.

4.2.2 Radical structuralism - the warrior

The *warrior* also perceives quality requirements and product characteristics as having an objective existence, but assumes that there are conflicting interests and is therefore concerned with whose quality requirements are being addressed. For example, is the management quality requirement being satisfied by an IS at the expense of the operators' quality requirement? Quality is considered to be conflictual as it is not possible to satisfy the quality requirements of all the stakeholders.

Ehn & Kyng (1987) review the role of trade unions in systems design in Scandinavia. In the category of first generation projects are DEMOS, which was initiated by the Swedish Trade Union Federation under the title "Democratic Control and Planning in Working Life: On Computers, Trade Unions, and Industrial Democracy" (Sandberg 1983), and DUE, "Democracy, Development and EDP" initiated by the Danish Trade Union Research Council in 1976. Ehn & Kyng (1987) categorize UTOPIA, a collaborative project between the Nordic Graphic Workers' Union and research institutions in Sweden and Denmark to investigate computer support for integrated text and image processing, as second generation (Bodker et al. 1987). The principles for computer systems design on which the UTOPIA project was based include: 'quality of work and products, democracy at work, and education for local development' (Ehn & Kyng 1987, p. 32). Ehn & Kyng are concerned with the 'relation between capital accumulation and managerial control' and 'the role of class struggle at work and workers' resistance'. Changes in the labour process are driven by a desire for capital accumulation (or generation of profits) and the 'intensification of work and use of new technology are two basic strategies for capital accumulation'. They conclude that 'design of computer support is design of (conditions for) labour processes' (p. 51), that 'labour processes cannot be reduced to information processes' (p. 52), 'important aspects of labour processes - in relation to design of computer support - cannot be formally described' and that a collective resource approach is needed, particularly in situations where the conditions are less ideal than the conditions which prevailed in the UTOPIA project.

Greenbaum (1995) has reviewed the development of IT and changes in work in the twentieth century and reaches the conclusion that management objectives have not changed: the aim is to reduce cost and to increase productivity. The introduction of IT has enabled organizations to routinize and standardize jobs to the point where operators follow scripts, as in telephone banking (p. 84). With the introduction of business process redesign Greenbaum argues that the intensification of work has spread to managerial grades, who have seen the clericalization of professional work (for example, they do their own word-processing and answer the telephone) accompanied by greater productivity demands (p. 86).

Although it might be argued that the functionalist and radical structuralist approaches both have roots in objectivism, the regulative viewpoint of the functionalist assumes that interests are shared (there is debate about the means but not the ends) while the radical structuralist view assumes that there are some real-world structures that reflect a basic incompatibility of interests - quality requirements are not necessarily common to and shared by workers and managers.

The warrior metaphor assumes a basic incompatibility between the quality requirements of workers and management.

4.2.3 Social relativism - the liberal

The *liberal* considers quality to be socially constructed. Quality requirements are inter-subjectively agreed and therefore the participation of many of the parties affected by the IS need to be involved in agreeing what is to be done and how the quality of the intervention is to be judged. The situation is perceived to be one of general consensus, which means that the parties involved will be able to reach agreement concerning functional and quality requirements (Checkland (1990) points out that with interpretivist approaches an *accommodation* is the most likely outcome, of which consensus is a special case). The assumption is that differences in perception of what constitutes quality can be reconciled in the interests of the common good.

Hirschheim & Klein (1989) place ethnographic approaches in this paradigm, and in the IS domain cite the FLORENCE project as an exemplar Bjerknes & Bratteteig (1987). Checkland (1981) suggests that SSM is primarily an interpretivist method and that it is located in the social relativist paradigm, but also that it contains elements of radical change. This position has been disputed by Jackson (1982) and Hirschheim et al. (1995), who maintain that SSM is at heart a conservative approach that will serve to maintain the status quo.

The interpretivist approach to computer system development is typified by Lewis (1994), who states that:

> The image of organizations and social life that is now applicable is one of social systems whose members continually construct, share, dispute and confirm meanings, and thereby 'construct' reality. An ultimately unknowable reality can now only ever be appreciated and understood through mental frameworks. These are shaped by the values, interests, expectations and beliefs of societies, human organizations and individuals, which creates the possibility of there being 'multiple realities' or different interpretations of any situation. (p. 180)

The interpretivist approach views customer needs as a social construction and the process of quality requirements analysis as inseparable from social and political factors.

4.2.4 Neohumanism - the emancipator

The *emancipator* would also consider quality to be inter-subjective, but recognizes the presence of conflict and hence the exercise of power. The emancipator is thus concerned with constructing a notion of quality that takes into account the needs of the less powerful (less privileged) and the recognition of cultural repression. The emancipator adopts a critical stance and seeks to initiate change to improve the situation, recognizing that there is unlikely to be a consensus and that any definition of quality will be mediated through the exercise of power.

Hirschheim & Klein (1989) draw upon the work of the critical school and the idea of technical, practical, and emancipatory knowledge interests (Habermas 1972), as a basis for the critical approach adopted by neohumanists (table 4.1). The technical interest is concerned with control and labour; the practical interest is concerned with interpretation and language; and the emancipatory interest is concerned with criticism and power (Dahlbom & Mathiassen 1993; Flood & Jackson 1991).

Interest	concern	organization	metaphor
Technical	control	labour	engineer
Practical	understanding	language	facilitator
Emancipation	criticism	power	emancipator

Table 4.1: knowledge interests

Hirschheim & Klein (1989) find little evidence of IS development based upon critical thinking. Flood & Jackson (1991) describe Ulrich's (1983; 1987) work on critical systems heuristics (CSH) and criticize the method as being unable to address structural issues and for its Utopian stance (an inheritance of Habermas) - why should IS developers be expected to have the motivation to take account of parties who are affected by the IS development but are not involved?

4.2.5 Summary

The received opinion is that the majority of IS development is rooted in a functionalist paradigm, with a prevailing technical knowledge interest and a means-ends orientation. Similarly, much of the literature on TQM is functionalist and even where cultural issues are addressed it is still rooted in a mechanistic metaphor of organization (Vidgen et al. 1994). The four paradigm framework provides a powerful way of thinking about IS quality, but it does not provide a practical guide for the development of quality information systems. In the next section a multiple perspective framework for IS quality is introduced that will form the basis of an IS quality methodology.

4.3 A multiple perspective framework for IS quality

From the literature review conducted in chapter 2 it is clear that there are many different views of what IS quality might be and the four paradigm analysis above highlights the possibility of different approaches to IS development and the implications for IS quality. This author considers that the quality outcomes of an IS can be considered through three key aspects: the quality of the IS in terms of organizational effectiveness; the quality of the technical artefacts employed; and the quality of work-life that ensues from organizational work (figure 4.6). These three views of IS quality are represent by the disciplines of management, software engineering, and human resource management respectively.

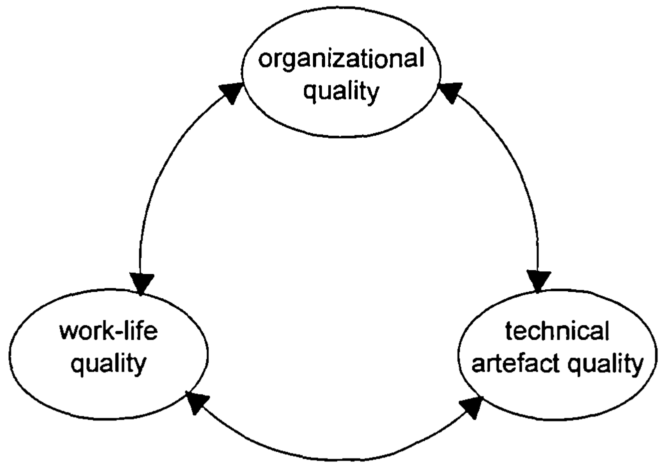


Figure 4.6: three views of IS quality outcomes

The themes also reflect the definition of an information system adopted in chapter 1, where organization context and technical artefacts were identified to be key concerns. The addition of work-life quality allows quality to be viewed from a more concrete perspective. For example, telephone banking might be highly efficient and effective for the organization and involve high quality software. From a work viewpoint it might be less satisfactory, involving deskilling, routinization, and the intensification of labour. The author has experience of accounting packages that are by any technical criteria poor quality: they are poorly designed with monolithic programmes that have "evolved" over time into a labyrinthine mess; have cumbersome user interfaces; have many thousands of reported errors; and are difficult and dangerous to maintain and enhance. However, the packages are in use in a significant number of large organizations and are successfully meeting business needs.

Although the framework presented in figure 4.6 could be relevant to the different paradigms described in section 4.2, the adoption of different paradigms would lead to potentially different outcomes. For example, a functionalist might embrace a socio-technical approach on the basis that the overall performance of the system will be enhanced by a better fit between personal needs and task needs and employee empowerment - everybody wins since there is greater job satisfaction and improved organizational effectiveness. A radical structuralist would argue that this is just a managerialist ploy to reduce staff and supervisory costs while getting greater performativity. It seems that the three views of IS quality of figure 4.6 will be insufficient by themselves and need to be supplemented by a view of the approach taken to the IS development process. Multiple perspectives can be used to provide a rich insight into the process of IS development and IS quality.

4.3.1 Multiple perspectives

Linstone (1985) has highlighted some shortcomings of the traditional (functionalist) perspective grounded in science and engineering. In this traditional worldview problems are defined with the assumption that they can be solved; Linstone (1985) argues that solving a problem creates new problems - we shift problems rather than solve them (p. 309). Rather than seek the best solution, we maximize our options, sacrificing efficiency for resilience, seeking to survive failure rather than to avoid it. Linstone also argues against: reductionism; a reliance on data and models as the only legitimate means of enquiry; the analyst as objective observer; individuals as types (but not as unique persons); and a linear, universal model of time.

	Technical (T)	Organizational (O)	Personal (P)
World view	Science-Technology	Social entity, small to large, informal to formal	Individuation, the self
Goal	Problem solving, product	Action, stability, process	Power, influence, prestige
Mode of enquiry	Sense-data, modelling, analysis	Consensual and adversary	Intuition, learning, experience
Ethical basis	Logic, rationality	Abstract concepts of justice, fairness	Individual values/morality
Other characteristics	Looks for cause and effect relationships	Agenda (problem of the moment)	Challenge and response
	Problem simplified, idealized	Problem delegated, factored	Hierarchy of individual needs
	Claim of objectivity	Reasonableness	Need for beliefs
	Quantification	Incremental change	Fear of change
	Use of averages, probabilities	Compromise and bargaining	Creativity and vision by the few
	Uncertainties noted (on one hand....)	Make use of uncertainties	Need for certainty
Communication	Technical report, briefing	Language differs for insiders, public	Personality important

Table 4.2: multiple perspective types and their paradigms (abridged from Mitroff & Linstone (1993), table 6.1, p. 100)

This traditional perspective with its roots in science and engineering is labelled by Linstone as the *technical* or T perspective. The multiple perspective approach has been developed in response to the shortcomings of the T approach. Linstone recognizes the seminal work of Allison (1971) and the contribution of Steinbrunner (1974). The multiple perspective approach augments the T view with *organizational*, O, and *personal*, P, views of a problem situation. The O perspective is concerned with social entities, processes, justice and fairness, the problem of the moment, and reasonableness. The P perspective is concerned with individuation, power and influence, values and morality, challenges, and a need for beliefs (Mitroff & Linstone 1993). Characteristics of the TOP model are summarized in table 4.2.

The different perspectives are concerned with how we consider a problem situation as distinct from what is being looked at. Linstone (1989) justifies the use of multiple perspectives firstly on the grounds that "each perspective yields insights not obtainable with the others", and secondly "the O and P perspectives are essential in bridging the gap between analysis and action" (p. 314). The T perspective focuses on analysis, but must be supported by O and P analyses when moving to implementation. The multiple perspective approach has its roots in the Singerian inquiring system (Churchman 1971, 1979), which in turn can be traced back to William James and the pragmatists.

However, the use of multiple perspectives is not without difficulties. Because the perspectives cannot be reduced in any meaningful sense to a common denominator, there are no programmable rules for balancing the requirements produced by the different perspectives. Indeed, the perspectives might reinforce each other, cancel each other out, or highlight conflicting requirements that can be used as a basis for discussion and action. Thus, in using multiple perspectives it is necessary for the practitioner to be able to use methods that reflect the different modes of inquiry and to exercise judgement to reach a balance of perspectives.

4.3.2 Multiple perspectives and IS development

One approach to multiple perspectives is viewpoint analysis. This is typically a hard view of the world in which an objective reality is seen from different viewpoints. For example, Kotonya & Sommerville (1992) are concerned with the external entities, which can be identified from data flow diagrams, of a system and their different interactions and information requirements; Hsia et al. (1994) develop specific scenarios for different user groups based on an analysis of the different event types that are required to accomplish a functional requirement. The software engineering approach tends to be multiple viewpoints of a single reality whereas with multiple perspectives there is a recognition of multiple realities related to a variety of O and P perspectives associated with different organizational and individual actors.

A richer implementation of the multiple perspective approach has been proposed for IS development in the Multiview methodology (Avison & Wood-Harper 1990, 1991; Wood-Harper & Avison 1992). Avison & Wood-Harper (1990) implement multiple perspectives in Multiview through a five stage methodology: analysis of human activity; analysis of information, which is implemented via structured methods; analysis and design of social-technical aspects; design of the human-computer interface; and design of technical aspects (p. 21). These five stages are presented as a waterfall structure (p. 22). More latterly, Wood-Harper & Avison (1992) have re-presented Multiview using an SSM-style nomenclature in which the five stages are reduced to a four box structure of human activity, information analysis, socio-technical analysis and design, and technical design. One benefit of this re-presentation of Multiview is the removal of the waterfall structure of the earlier work.

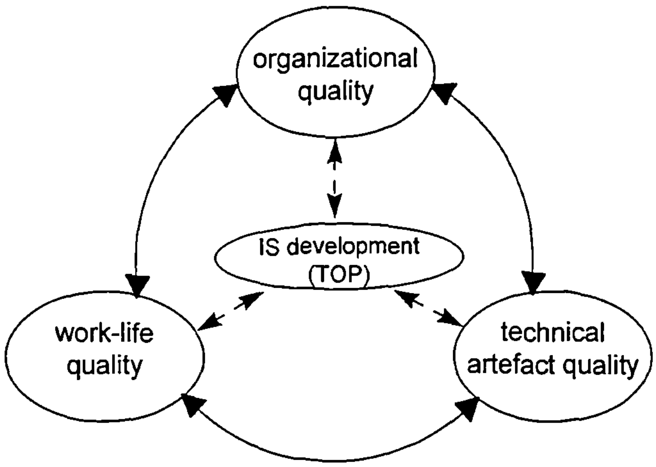


Figure 4.7: IS quality outcomes and a TOP approach to IS development

The Multiview stages technical design, human activity systems analysis, and socio-technical analysis and design appear to align well with the T, O and P perspectives respectively. Similarly, there is a correspondence between TOP model and the technical artefact quality (T), organizational quality (O), and work-life quality (P) outcomes shown in figure 4.6. However, there are important differences in definition. For example, the technical design stage of Multiview is oriented toward the details of computer system design, whereas the Linstone (1985, 1989) T perspective is a more general term that is equated with rationality and functionalism. Linstone would recognize a T perspective for the analysis of the organization that is supplemented by O and P views in implementation. In this author's opinion the TOP perspectives need to be used to inform the process of IS development as well as the content of the IS development methodology (figure 4.7).

A T perspective is concerned with a rational view of IS development that results in the construction of technical artefacts that will enable the creation of information systems in support of purposeful organizational activity. Thus, although Multiview (Avison & Wood-Harper 1990) includes the use of SSM for human activity system modelling it does so from a largely T perspective. The IS developer is largely outside of the situation and although methods are used that are relevant to all three IS quality outcomes the T perspective and a mechanistic metaphor of organization are dominant.

The O perspective is typified by a cultural metaphor and the need for a shared understanding between different group members and between different groups. The O perspective is a social view of organization and IS development that can be made tangible through the notion of organizational learning (Argyris & Schön 1978; Argyris 1992). With the O perspective we can view IS development as a learning cycle of discovery, invention, production, and generalization (Argyris 1982). To be truly effective the O perspective needs double-loop learning to cater for the surfacing and challenging of deep-rooted assumptions which were previously unknown or undiscussable.

The P perspective is concerned with individuals. Traditionally the T and O perspectives have received considerable attention in IS research. The O and P perspectives will to a large extent overlap, but the distinction between the O and P perspectives is useful since it allows the analyst to think of organizational units (these might be formal, such as departments and project teams or less informal, such as membership of a golf club) while remembering that these units comprise individuals with weaker and stronger affiliations to various organizational units. The P perspective is more problematic since it is concerned with individuals and their specific desires, personality traits, concerns about status and influence, likes and dislikes, bias, and so on. When talking about an O perspective the individual is generalized into abstractions such as stakeholder groups, which although still a potential threat by comparison with the objectivity and distance of the T perspective, is discussible in a way that individuals are not.

Knights & Murray (1994) give particular importance to political processes at group and individual levels:

> This political process concerns the struggles of individuals to pursue careers and achieve a measure of security in uncertain and competitive market conditions. For us, political process is not an aberration or pathological condition. Rather, it is the dynamic at the heart of organisational life played out in conditions of considerable inequality. This challenges functionalist organisation theory which, in a variety of forms, views the organisation as a rational and objective entity. It also challenges the over-rationalised versions of organisational process that managers readily give to their actions. (p. 245)

Thus Knights & Murray argue that management in general and IS development in particular is first and foremost a political process with O and P motivated actions being legitimated by recourse to T factors. In the current author's opinion such a view is no more demonstrable than functionalism. However, it is a salutary reminder to keep one's eyes on T, O and P issues in IS development.

4.3.3 Multiple perspectives and TQM

From the standpoint of TQM the T perspective is represented by quality function deployment (QFD) in which customer demanded qualities (the voice of the customer) are deployed through all stages of product and service development and operation. This is a rational and engineering view of quality. Attention to an O perspective can also be found in TQM in the recognition of a need to create a quality culture. The P perspective in TQM is represented by a desire for employee empowerment. Although the TOP framework bolsters TQM by providing it with a coherence and theoretical basis it might also be argued that the use of multiple perspectives in TQM is rather narrow and aimed at increasing efficiency (cost and time) while reducing management and supervisory overheads.

4.3.4 Summary

This author considers that there are three distinct, albeit inter-related, roles for multiple perspectives:

- to accept multiple realities (*Weltanschauungen*);
- to recognize approaches to IS development other than technical rationality (TOP);
- to consider IS quality outcomes in the domains of organizational activity, technical artefacts, and work-life.

All three approaches contribute to the richness of IS development and IS quality and are used to inform this research. However, the author also recognizes that there are criticism of the multiple perspective approach that need to be addressed. For example, it can be argued that the Multiview methodology is a mix of methods that constitute a paradigmatic mismatch resulting from an attempt to combine SSM, an interpretivist approach, with structured methods, which are steeped in functionalism. If this is the case then it could be argued that the multiple perspective approach to IS quality is flawed (from a theoretical standpoint at least). In the next section the arguments for the paradigms as separate modes of thinking is explored.

4.4 Paradigmatic closure and critical systems thinking

Burrell & Morgan (1979) recommend that methods are developed within and faithful to specific paradigms:

> We firmly believe that each of the paradigms can only establish itself at the level of organizational analysis if it is true to itself. Contrary to the widely held belief that synthesis and mediation between paradigms is what is required, we argue that the real need is for paradigmatic closure...... the paradigms reflect four alternative realities. They stand as four mutually exclusive ways of seeing the world. (pp 397-8)

This is a strong statement. Following this recommendation would lead to the development of four separate approaches to IS development and IS quality, each reflecting the different assumptions about objectivity and subjectivity, regulation and radical change. The implications of paradigmatic closure can be seen in the work of Lewis (1994), which has strongly interpretivist underpinnings:

> ...the best known approaches to data analysis have at their heart objectivist assumptions: they are based on the premise that data structures exist, independently of the observer, in the real-world, and that the result of data analysis will be a description of those real-world structures in the form of a data model. Entity-relationship modelling, normalization or object-orientation each provide a different language and grammar for such descriptions whilst sharing those same underlying assumptions. This prevents a direct use of those approaches in conjunction with SSM, for to accept those assumptions is incompatible with the phenomenological stance of SSM. (page179)

Lewis proposes that an interpretive data model 'would be clearly different in kind to the models produced by conventional data analysis, and will only ever be meaningful in respect to the definition of a particular conceptualised system' (Lewis 1994, p. 182).

One of the arguments for adopting a paradigmatically closed approach is that unless the purity of the paradigms is maintained there is a risk of emasculation as a result of different modes of enquiry becoming wrapped up within a single (typically functionalist) framework. There is concern about the mixing of incommensurate approaches within a single methodology, such as the mix of human activity system modelling, structured methods, socio-technical analysis, and technical design in Multiview. This level of incommensuarability is compounded by the incommensurability of the multiple perspectives of the TOP approach proposed in section 4.3. In terms of theory and practice this could represent a major objection to an IS quality methodology that is based upon a seemingly ad hoc selection of methods that are theoretically incommensurate and/or practically incompatible.

However, the issue of which approach to IS development to use in a given situation could not be decided by reference to the four paradigm framework itself, since this would be to privilege one of the paradigms over the others. Thus, a meta-paradigm framework, such as that proposed in Total Systems Intervention (TSI) by Flood & Jackson (1991) would be needed to provide a way of discussing the issue of which paradigm is to be adopted. To understand the implications of paradigmatic closure it is useful to make a detour into an area which although it might seem tangential provides ultimately an illumination of the issues of subjectivity and objectivity and a way forward from paradigmatic closure.

There is a history of debate concerning SSM and its potential for radical change. Checkland (1981) placed SSM in the subjective/regulation paradigm of Burrell & Morgan (1979), but with an element of radical change:

> Also given the analyst's complete freedom to select relevant systems which, when compared with the expression of the problem situation, imbody either incremental or radical change, the area occupied must include some of the subjective/radical quadrant. (p. 281).

Jackson (1982) in a critique of soft systems approaches argued that the result of applying SSM will be regulative rather than radical, that the potential for radical change of *Weltanshauungen* will not be realized in practice. The basic premise for this argument appears to be that SSM is wholly interpretivist and lacking in a positivist element that would provide a theory of how order and cohesion are achieved. This means that SSM cannot distinguish between the structurings that are historically contingent and amenable to change and those which are physiological and therefore not amenable to change. Checkland's (1982) response maintained his view that there is always the *potential* for *Weltanschauungen* to change:

> It would be legitimate to argue that soft systems methodology *inevitably* props up the *status quo* if, and only if, it were possible to demonstrate that problem-owners' *Weltanschauung* were immovable. All of the experience with the methodology, as well as much observation of everyday life, suggests that *Weltanschauung* do change, sometimes incrementally, sometimes radically. (original emphasis). (p. 39)

In his comment on Checkland's reply Jackson (1983) reasserts the view that SSM is an interpretive method and has a bias towards regulation:

> I would argue that when the Checkland methodology is used in circumstances where there are great disparities in the wealth, status and information resources of the different stakeholders (as is the situation in very many organizations in the UK) the outcome is all too predictable. The learning system will produce 'learning' - a re-negotiation of perceptions of the world - highly favourable to those who already have power in the system. Power in the debate at stages 5 and 6 of the methodology will be drawn from the existing order of domination and when it is applied it will produce a 'consensus' which reflects existing social arrangements. (p. 112)

Jackson's views are echoed by Hirschheim et al. (1995), who state that radical structuralists would 'insist that systems thinking is the ideological vehicle by which the dominant elite will seek to rationalize and legitimize primarily those designs that do not threaten their privileges and interests' (p. 127). They conclude that SSM is missing an effective means of participation:

> Emancipatory systems can only be designed through genuine democratic participation. Neither in the classical nor in the recent version of SSM is there an explicit discussion of the meaning and significance of participation let al.one of the difficulties of implementing a participatory design approach. (p. 127)

Burrell (1983) in a review of Checkland's (1981) "Systems Thinking Systems Practice" concluded that SSM did not embrace fully phenomenology, that it reflected a desire to be scientific ('overly Popperian' and 'seems to resonate well with some concerns of F. W. Taylor'), and that it was managerialist ('it is interested only in change which is acceptable to the powerful and is reformist rather than revolutionary'). As with Jackson (1982, 1983), Burrell maintains that there is little evidence to connect SSM with the critical theory of Habermas as 'the methodology is only emancipatory for those who already possess (a degree of) freedom' (p.125). Checkland (1983b), in a response to Burrell, restates his belief that *Weltanschauungen* can change and that 'there must be hope that more than a demonstration of incommensurability could emerge' (p. 129).

At this point the debate appears to have reached an impasse with neither side willing to give ground to the other. However, there is a way of progressing this debate, particularly if one is interested 'in dissolving inherited problems rather thanin solving them' (Rorty1989, p. 20). Mingers (1984) identified four schools of thought that underpin subjectivism: phenomenology, ethnomethodology, the philosophy of language, and hermeneutics. Mingers distinguishes between strong and weak subjectivism. In the strong form the approaches 'implicitly recognize an objective social world but are unable to deal with it adequately because of their subjectivism' (p. 89). Furthermore, the strong subjectivist approach is logically inconsistent in the Popperian sense as when the proposition is applied to itself it casts doubt on its own propositions; strong subjectivism can only be accepted by making an act of faith and therefore there is equally good reason not to accept it. From a practical viewpoint, Mingers argues that '[w]e cannot bring about what we want merely by thinking about it and often we are continually frustrated despite our best efforts' (p. 92). SSM is categorized as being firmly within the school of the individual phenomenology of Schutz (1976) and also strongly idealist in the belief that changes in people's ideas can bring about changes in the world. Mingers' view of SSM leads him to place it solidly within the interpretivist quadrant of the Burrell & Morgan (1979) framework.

With respect to the Checkland/Jackson and Checkland/Burrell debates Mingers argues that attention needs to be redirected from subjectivity and objectivity to *intersubjectivity*, in which objective (structure) and subjective (agency) elements are present as 'we continually move from one to the other and back again in an endeless but hopefully convergent circle reflecting the complete inter-dependence of the two' (p. 101). Mingers concludes by recommending that researchers investigate the work of Giddens (1976, 1979). Although this author would argue that structuration theory is a co-presence, or duality, of objective and subjective rather than a movement between the two, the Mingers paper is one of the earliest to recognize the importance of structuration theory for IS research.

4.5 Symmetry in IS development

Rather than pursue the objectivist/subjectivist debate or the role of power in SSM a more fruitful route is to explore intersubjectivity, which is better envisaged as a *symmetry* and *duality* of objectivity and subjectivity. Two approaches that reject the object/subject dualism are structuration theory and actor network theory.

4.5.1 Structuration theory

Berger and Luckman (1967) proposed a framework where subjective meanings (externalization) become objective facticities (objectivation) which then 'act back' as they socialize present and future generations (internalization). Reality construction is the dialectical relationship of these three moments. In his work on structuration theory Giddens (1984) has moved further from the paradigmatic closure of the Burrell and Morgan framework and the dialectics of Berger and Luckman by conceiving the objective and subjective to be co-present (Willmott 1990). Giddens resolves the agency versus structure debate by considering it to be a *duality* rather than a *dualism* of independent phenomena. Figure 4.8 depicts human action and social structure in three dimensions with three modalities: *interpretative scheme* - stocks of knowledge drawn upon by human actors to make sense of their own and others' actions; *facility* - the ability to allocate resources (human and material); *norm* - actions are sanctioned by drawing upon standards concerning "good" and "bad". Human action not only reinforces the existing structures of meaning, but can also change existing structures and create new structures. Structuration theory allows for unintended consequences of intentional human activity and recognizes practical consciousness, that is, people are more knowledgeable than 'what they can say'.

Walsham & Han (1995) have reviewed the use of structuration theory in IS research and note that it has been used in Group Decision Support Systems (Poole & DeSanctis 1989), in relation to the reproduction of culture and for understanding technology in organizations (Orlikowski 1992). One of the most thorough explorations of structuration theory in IS development and IS use is provided by Walsham (1993). Walsham & Han see a range of roles for structuration theory in IS research: as a basis for operational studies; as a meta-theory; and as a source of specific concepts, such as routinization. They conclude that structuration theory is not incompatible with IS approaches, and suggest that SSM would benefit from a structurational view of social reality. Given the debate concerning the critical potential of SSM the introduction of structuration theory would seem to be a significant area for the development of SSM.

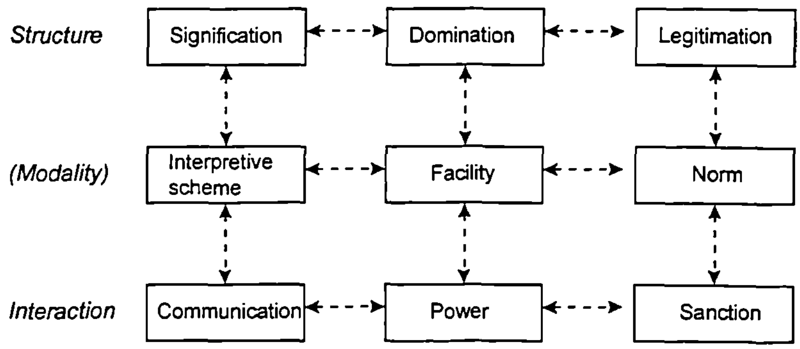


Figure 4.8: structuration theory (Giddens 1984)

However, structuration theory is rather general and concerned with structures of meaning, structures of domination, and structures of legitimation. Actor network theory also proposes a symmetrical approach to object and subject worlds but is rather more specific about the role of technology than is structuration theory.

4.5.2 Actor network theory

Walsham and Han (1995) note Garnsey's (1990) criticism of Orlikowski's (1992) use of structuration theory in which technology is treated as a structural property 'without emphasising its contrast with Gidden's view of social structures as memory traces in the human mind' (Walsham & Han 1995, p. 80). Actor network theorists would argue structuration theory privileges human actors over non-human actors, such as technology. Monteiro & Hansleth (1995) also criticize Orlikowski's (1992) structuration theory-based research into the implementation of a CASE tool. No description is provided of the CASE tool itself, despite Orlikowski's opinion that the CASE technology constituted a highly visible indicator of a program to streamline the systems development process. Monteiro & Hansleth conclude that although structuration theory helps us to see that IT both restricts and enables action it is not sufficiently 'fine-grained' to address the specifics of technology. They suggest that actor network theory can be used to keep technology present.

The taxonomy of IS development methods (Bickerton & Siddiqi 1992) introduced in chapter 2 contained a category for network based approaches, although it was recognized that these ideas have yet to be incorporated in any substantial way into IS development methods. Actor network theory (ANT) (Callon 1986, 1991; Latour 1986, 1987, 1991) at first sight appears to have similarities with structuration theory, but on closer inspection has some significant differences, particularly in the treatment of technology and non-human actors in general. In ANT the distinction between human and non-human actors is removed and all actors are given equal status. The same language of problematization, interessement, enrolment, mobilization, and dissidence (betrayal) is used for fishermen, scallops, and scientists in Callon's (1986) account of the domestication of scallops and fishermen of St Brieuc Bay.

Actors combine into heterogeneous networks, one type of which is the techno-economic network (Callon 1991):

> Techno-economic networks are composite. They mix humans and non-humans, inscriptions of all sorts, and money in all its forms. Their dynamics can only be understood if we study the translation operations which inscribe the mutual definition of the actors and intermediaries put into circulation and 'read' the relevant inscriptions. Further, the translation operation is itself regulated by more or less local and revisable conventions. (p. 153).

Alignment of a network involves the translation of actors' interests through a process of inscription. When successful, translation produces a 'shared space, equivalence and commensurability' while 'unsuccessful translation means that players are no longer able to communicate' (Callon 1991, p. 145). The idea of actors having interests resonates with the *Weltanschauung* of SSM (with a major exception that soft systems thinkers and interpretivists are very uncomfortable with the idea of non-human actors possessing or being ascribed interests) - unaligned networks have incommensurate interests and the process of network formation requires a series of translations that results in commensurate interests. In some ways this returns us to the arguments of Jackson & Checkland and the possible conclusion that ANT would be a regulative/conservative basis for IS development. This debate lead to intersubjectivity and structuration theory in the previous section. ANT has a contribution to make here also:

> The less convergent a network, the less it is irreversibilised and the more the actors composing it can be understood in terms of concpets such as strategy, the negotiation and variation of aims, revisable projects, and changing coalitions. Under such circumstances analysis has to start with actors and chart their fluctuating interactions. The trail is still hot. Information is scarce, contradictory, asymmetrical, and difficult to interpret and use. Uncertainty rules the day. (Callon 1991, p. 154).

For aligned networks:

> At the other extreme, in completely convergent and irreverisibilised networks, the actors become agents with precise objectives and instruments for establishing hierarchies, calculating costs and measuring returns. .....Controversy and disinteressement (to use the language of translation sociology) is highly unlikely. The paradox is that the actors have no choice, since they are 'acted' by the network that holds them in place. (Callon 1991, p. 154).

Clearly there is a feeling in ANT of a duality of structure and agency inasmuch as networks are created through the actions of human and non-human actors while networks at the same time constrain what actors can do. With respect to critical issues, Latour (1991) argues that:

> Domination is an effect not a cause. In order to make a diagnosis or a decision about the absurdity, the danger, the amorality, or the unrealism of an innovation, one must first describe the network. If the capability of making judgements gives up its vain appeals to transcendence, it loses none of its acuity. (p. 130).

ANT assumes that actors are motivated by interests. The role of interests in network formation is now considered.

4.5.2.1 Interests

Latour proposes that we are faced by a 'gamut of weaker and stronger associations' (Latour 1987, p. 259), where to understand what facts and machines are is the same task as understanding who the people are. These networks will be shorter or longer, with weaker and stronger associations, possibly containing obligatory passage points (strongholds in the network, such as the law of gravity). Thus, we can consider a sophisticated word-processor, such as Microsoft's Word for Windows, as a *black box* that hides many complicated parts and is supported by a complex commercial network of sales, support, marketing, and product development. Whether we are concerned with scientific facts or with technical artefacts:

> The problem of the builder of 'fact' is the same as that of the builder of 'objects': how to convince others, how to control their behaviour, how to gather sufficient resources in one place, how to have the claim or the object spread out in time and space. In both cases, it is the others who have the power to transform the claim or the object into a durable whole (Latour 1987, p. 131).

Latour outlines a number of strategies for enrolling others in the creation of a black box: to appeal to the other's explicit interests; to get the others to follow our interests; to suggest a short detour (this is particularly strong when their road is blocked); to reshuffle interests and goals by tactics such as inventing new goals, inventing new groups; by becoming indispensable to the others. To build a black box others have to be enrolled so that the black box is bought and spread across time and space; once enrolled they need to be kept in line so that what is disseminated remains broadly the same.

The generation of black boxes through networks raises a particular issues: who are the *others* and what are their *interests*. Latour seems to assume that the identification of others and understanding their interests is not especially problematic. Interests are defined as 'inter-esse', lying between actors and their goals. This seems to assume that goals have an objective existence and that people will behave rationally in pursuit of these goals. Resources will 'jump' at the chance to translate claims and technical artefacts that further their goals (Latour 1987, p. 109). The formation of black boxes is promoted when interests move in the same direction.

In considering who the actors are and what their interest is the techniques of stakeholder analysis, amended for human and non-human stakeholders (Vidgen & McMaster 1996), and multiple perspectives (TOP) should be relevant.

4.5.2.2 Quasi-objects

In a later work, "We have never been modern", Latour (1993) argues that one aim of the modernist project is purification - the separation of an objective and given natural world from a socially-constructed subject world. Modernism contains a paradox insofar as it espouses separation of natural and social worlds, while relying upon their inseparability for its successes. However, the middle ground is more than a meeting place of natural and social worlds:

> We do not need to attach our explanations to the two pure forms known as the Object or Subject/Society, because these are, on the contrary, partial and purified results of the central practice that is our sole concern. The explanation we seek will indeed obtain Nature and Society, but only as a final outcome, not as a beginning. Nature does revolve, but not around the Subject/Society. It revolves around the collective that produces things and people. The Subject does revolve, but not around Nature. It revolves around the collective out of which people and things are generated. At last the Middle Kingdom is represented. Natures and societies are its satellites. (Latour 1993, p. 79)

With respect to IS, the quest for purification leads us to make artificial distinctions, such as the separation of context from technology, conceptual model from real-world, incremental change from radical change, analysis from design, and quality requirement from quality characteristic. The tendency is toward purified subject and object worlds that are either kept separate or explored through dialectical movements. However, dialectics is not a solution:

> Linking the two poles of nature and society by as many arrows and feedback loops as one wishes does not relocate the quasi-objects or quasi-subject that I want to take into account. On the contrary, dialectics makes the ignorance of that locus still deeper than in the dualist paradigm since it feigns to overcome it by loops and spirals and other complex acrobatic figures. Dialectics literally beats around the bush. .....Quasi-objects are much more social, much more fabricated, much more collective than the 'hard' parts of nature, but they are in no way the arbitrary receptacles of a full-fledged society. On the other hand they are much more real, nonhuman and objective than those shapeless screens on which society - for unknown reasons - needed to be 'projected'. (Latour 1993, p.55)

Latour proposes a constitution that retains elements of pre-modernism, modernism, and postmodernism (Latour 1993, p. 66). This constitution has been paraphrased and amended with respect to IS development (Vidgen & McMaster 1996):

- the non-separability of the common production of IT and organizational context;
- the inseparable objectivization of IT and subjectivization of organizational context;

- freedom is a capacity for sorting and recombining sociotechnical imbroglios;
- the replacement of the clandestine proliferation of technological/organizational hybrids by their regulated and commonly-agreed-upon production.

The modernist division between nature and society has scientists speaking on behalf of things which cannot speak for themselves (mutes) and sovereigns speaking on behalf of subjects. The scientist represents faithfully nature and the sovereign represents what the subjects would have said if they had all been able to speak at once. In terms of system development there are developers who represent "things", such as software, and users who represent their communities (often known as 'key' users). However, there is the possibility of a double betrayal: the developers might be talking about themselves rather than the technology that they represent and the key user might be pursuing his/her own interests rather than those of the user community at large. How can we know whether the developers and user representatives translate or betray? Latour argues that it is our attempt to separate nature and society that is the problem (p. 142-145). Representing nature and representing society are not two problems of representation but one. The 'parliament of things' is a place where technology is present with its representatives (suppliers and developers of IT) who speak in its name; society (users) is present , but with the objects that form its ballast. Latour argues that this view need not lead to a revolution since all that it requires is a ratification of what we have always done, albeit clandestinely.

4.5.3 Implications for IS development

ANT would lead us to see the concern of IS development as the transformation of a 'lash-up' (Law 1986) of heterogeneous, disorderly, and unreliable allies into an automaton, which resembles an organized whole and can be considered a black box. For the IS to maintain its blackness the IS developer has to exercise control at a distance, to ensure that the computer system is used as intended or at least within certain bounds. Similarly, the user manager has an interest in ensuring that work procedures are followed and might inscribe these procedures through training courses and manuals. If these inscriptions are not strong enough then further inscriptions, such as increased supervision might be introduced. Technology might be enrolled, as it is in telephone banking where the entire exchange between banking clerk and customer is scripted and subject to surveillance by a supervisor, to make yet stronger inscriptions. Perhaps it is appropriate to see domination as an outcome of network formation rather than as a cause.

One implication of ANT is that all actors are to be treated equivalently, whether they be developers, users, development methods, CASE tools, training courses, user manuals, office space, developer skill, hardware, coffee machines, Murphy's law, fate, and so on. These are the heterogeneous allies that must be lashed up. Button (1993) is critical of ANT and refers to Law's (1986) description of a Portugese Galley which is a product of men, sailcloth, wood, etc. Button points out that:

> However, we should presumably also say of air (because men must breathe), of food (because men must eat), of microbes (because during the course of these things people would be sick)......Any list of 'actors' in their sense is likely to be only a very short and - given their approach - quite arbitrary selection from the effectively infinite list of actors involved (Button 1993, p. 23).

Button then criticizes ANT for not addressing the details of the associating of elements in the network and argues that what is missing is an account of the working practices that resulted in the resources coming together and from which a galley emerged. Another way of viewing this criticism is that ANT is a useful way of describing network development, such as Latour's (1984) account of the development of pasteurization, but that it is lacks explanatory power. Latour (1991) recognizes this and argues that:

> The *description* of socio-technical networks is often opposed to their *explanation*, which is supposed to come afterwards. Critics of the sociology of science and technology often suggest that even the most meticulous description of a case-study would not suffice to give an explanation of its development. This kind of criticism borrows from epistemology the difference between 'how' and 'why', between stamp-collecting - a contemptible occupation - and the search for causality - the only activity worthy of attention
>
> ....The explanation emerges once the description is saturated. The impression that one can sometimes offer in the social sciences an explanation similar to those of the exact sciences is due precisely to the stabilization of networks, a stabilization that the notion of explanation simply does not 'explain'!

> ....There is no need to go searching for mysterious or global causes outside networks. If something is missing it is because the description is not complete. Period. Conversely, if one is capable of explaining effects of causes, it is because a stabilized network is already in place. (Latour 1991, pp. 129-130)

At the very least, ANT provides a framework for thinking about human and non-human actors on a common basis rather than a simple dualism of social and technological issues. Furthermore, by describing case studies of IS development using ANT it is possible that some common themes will emerge which will provide a basis for qualitative generalizations that can be used to inform the practice of IS development.

4.6 The IS quality framework re-presented

The IS quality framework presented in figure 4.7 will be used to inform the development of an IS quality methodology. One contribution of actor network theory is to reframe organizations (subject world) and technical artefacts (object world) as inseparable, each shaping the other, with separation only possible as a temporary outcome of IS development. Mediating between organizational context and technical artefact is work, which can be seen as creating organizations through the deployment of technical artefacts.

However, this is not the social construction of reality. In this author's opinion, following Latour, it would be equally reasonable to view the structures of organization as objective givens (as we find out all too often when we bump up against them) and technical artefacts as intensely social, being held together by suppliers, developers, users, and so on. More pertinently, it is perhaps better to think of IS development as a process of creating networks of heterogeneous allies - the longer the network and the stronger the links then the more irreversible (successful) the IS development. This approach does de-emphasize critical aspects, which become outcomes of IS development rather than starting points. In this author's opinion the best that an IS developer can do in practice is to develop a critical awareness and sensitivity; IS development founded on emancipatory ideas is not a practical proposition.

The perspectives of the TOP model are now seen to be inseparable; any separation is an outcome of IS development rather than a beginning. In forming networks and appealing to interests of actors then the TOP model is a useful device that should be applicable to all actors, whether they be human or non-human. In practical terms this might mean simply that one should think about TOP perspectives when talking about technology as well as organizational issues.

But does this mean that we should do things differently? Latour would argue that this is what we have always done, albeit clandestinely. This author also intends to continue doing what we have always done in IS theory and IS practice, but to be more sceptical of claims that technology and organizations, conceptual models and real-world problem situations, are separable. Perhaps they are, but only as outcomes of a process of IS development.

Chapter summary

The chapter began with the development of a generic framework for quality that could be applied to any product. This approach was shown to be largely within the functionalist paradigm. Analysis of IS quality using different paradigms suggested that there are alternative and possibly conflicting conceptualizations of IS quality. The multiple perspective framework was proposed as a means of avoiding the limitations of a rationalist approach to IS development and IS quality. The use of the TOP framework to inform the content of an IS development methodology and to inform the IS development approach raises the issue of paradigmatic incommensurability, which lead to a review of symmetric views of object and subject worlds. The IS quality framework was then reinterpreted in the light of the debate concerning paradigmatic closure. This framework is used to inform the IS quality methodology developed through empirical study and described in chapter 5.

5

Development of the methodology - ISDM/Q

Introduction

In this chapter the first two phases of the fieldwork that led to the development of a quality approach to IS development is reported. The resulting and provisional form of the methodology, ISDM/Q, is described in the second half of the chapter.

The fieldwork has been conducted at the military aircraft division of British Aerospace (Defence), a large organization and that involved all aspects of the design and manufacture of aircraft. BAe is a major participant in the European Fighter Aircraft (EFA) programme together with Germany, Spain, and Italy. BAe headquarters are in Warton, Lancashire with further sites throughout the UK, the major centres being Brough, which is on Humberside, and Farnborough in Surrey. The empirical research reported in this thesis was sponsored by the Software Quality Directorate of British Aerospace and had the following terms of reference:

> To develop and apply an operational methodology for defining and agreeing a relevant notion of use quality, taking into account the concerns of multiple stakeholders.

The fieldwork was divided into three phases and spanned the period June 1993 through October 1995 (table 5.1).

phase	description
1	literature survey and investigation of system development practice leading to the definition of the approach to be taken to IS quality (June 1993 - October 1993);
2	case studies of IT applications and the development of a quality approach to IS development - ISDM/Q (November 1993 - August 1994);
3	operationalization and testing of the ISDM/Q via action research (September 1994 - October 1995).

Table 5.1: phases of the fieldwork

At the outset of the first phase the empirical research was loosely structured, being organized around the general objective of finding out about the system development process within BAe and the quality issues perceived by the system development staff. As the interviews progressed common themes began to emerge that formed a basis for more structured interviews. In the second phase two case studies of implemented information systems were made with an emphasis on user and organizational viewpoints.

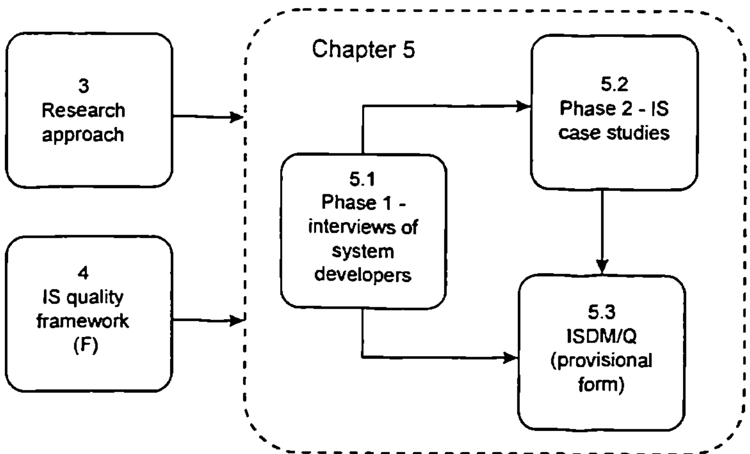


Figure 5.1: structure of chapter 5

This chapter concludes with a provisional description of the quality approach to IS development (ISDM/Q) which was developed as a result of the first two phases of the fieldwork and the IS quality framework described in chapter 3. The structure of chapter 5 is shown in figure 5.1. In the third phase of the fieldwork the ISDM/Q was applied via action research. The experiences of using and developing the ISDM/Q are reported in chapter 6.

5.1 Phase 1: interviews of system development staff

All of the interviews were carried out with personnel from CAE & Technical Computing (CAE being an acronym for Computer-Aided Engineering), a department within Airframe Technology, which is in turn part of the Technical Directorate of British Aerospace (Defence) based at Warton. The CAE & Technical organization structure, including the Software Quality Group, are shown in figure 5.2.

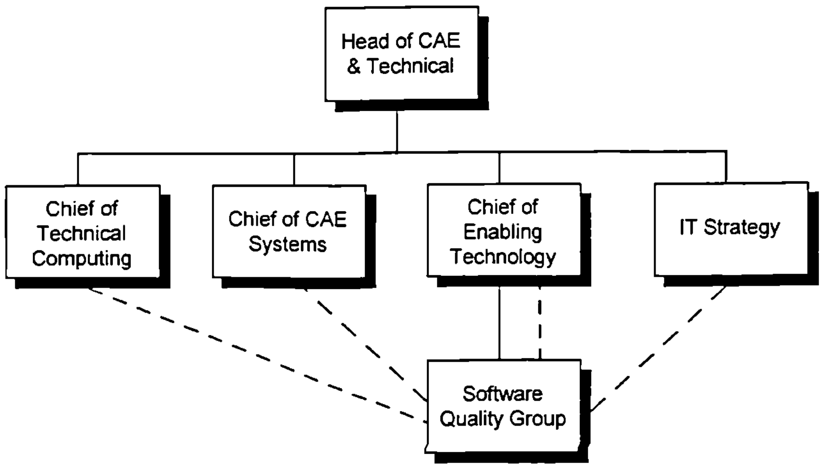


Figure 5.2: CAE & Technical organization structure

The three managers responsible for software development within CAE & Technical are each responsible for around 30 staff. For line management purposes the Software Quality Group (SQG) reports through the Chief of Enabling Technology, but has responsibility for the co-ordination of software quality activity across all CAE & Technical departments. Strategy is a small group (around 5 staff) which addresses issues such as standardization of hardware and the development of common applications. The interview schedule is shown in table 5.2.

The approach taken to gaining an understanding of the system development environment was to begin with open-ended, unconstrained interviews and to derive a semi-structured format as the interviews proceeded. This reflected the exploratory nature of the first phase. The typical structure of the interviews that emerged was to ask interviewees to:

- describe their area (staff, development environment, customers, etc.);
- give brief details of the systems supported;
- to identify a system that they think their customers would perceive to be 'good quality' and to justify why (the aim was to understand the assumptions developers hold about what users think constitutes a good quality system);
- to identify 'a less good quality' or 'poor quality' system (one that the developers feel uncomfortable with). Why is this system perceived to be poor quality by the users? This question was used as a means of leading into a more general discussion of the factors that can lead to loss of quality;
- to reflect on the differences between the good quality and the poor quality system;
- describe how they manage and monitor the level of customer satisfaction with their products and services.

Date	job title
05/08/93	Chief of Enabling Technology
12/08/93	Chief of Technical Computing
24/08/93	Chief of CAE Systems
24/08/93	Project Leader - Software Engineering (Enabling Technology)
30/08/93	Project Leader - Publications/Engineering Support (Enabling Technology)
13/09/93	Software Quality Group

Table 5.2: interview schedule for phase 1of the research

Due to security constraints, it was not possible to tape-record interviews and therefore hand-written notes were taken at each interview and typed up immediately afterwards. The interview notes were reviewed by BAe quality directorate staff, but have not been reviewed by the interviewees. However, a phase 1 project report, which contained considerable detail of the interview notes, was produced for the project sponsor and distributed to all interviewees for comment prior to finalization of the contents.

5.1.1 Background to CAE & Technical

At the time of the interviews the development activity of CAE & Technical systems fell into two main categories: mainframe applications and work-station applications. Mainframe applications are developed using the fourth generation language Natural (and/or COBOL in the case of older applications) running on ADABAS and DB2 databases. Applications are run under MVS/TSO on mainframes operated by the IT directorate (the IT directorate and the operation of mainframe computing has since been out-sourced). Work-station applications are developed on the DEC VAX platform, together with a limited amount of UNIX-based development. As would be expected given current technological trends towards distributed processing, client/server architectures, and open systems, there is a blurring of the distinction between mainframe and work station applications and UNIX is perceived as the future direction for much of the development work.

The standard development methodology is SSADM (Structured Systems Analysis and Design Method) version 4, although knowledge-based applications use a modified form of the KADS methodology. Sitting alongside of SSADM and KADS are in-house Technical Computing Standards & Procedures which also encompass project management (a variation on PRINCE - Projects in Controlled Environments - is used) and quality assurance. The technical standards are applicable to non-avionic software, such as management information systems; flight control software is developed by a separate department, Systems Computing, who use a variant of HOOD (hierarchical object-oriented design) and are subject to stringent safety critical constraints. The Software Quality Group (SQG) are aligning the Technical Computing Standards with the ISO9000 series of standards as part of an exercise in gaining ISO third party accreditation. Various CASE tools are used with the standard recommendation being Select for SSADM. There is a wide range of systems development activity in CAE & Technical (with the exception of flight control software) including traditional management reporting applications, knowledge-based applications, computer-aided engineering (CAE) and multimedia.

5.1.2 Interview findings

Analysis of the interview notes resulted in a number of themes being identified. These have been categorized as follows:

- *customer/supplier*: the relationship the supplier has with the customer, including service and customer care;
- *product*: the customer's view of the product in use;
- *socio-political*: organizational and power-related issues;
- *process*: the supplier's view of the development process and the software product;
- *technology*: technological issues associated with the development of information systems.

Issues identified during the interviews are presented in table 5.3, which provides a sub-categorization for each of the main categories above. Specific points are identified by an IREF code which is used in the following interpretation of phase 1 for cross-referencing purposes.

5.1.3 Reflections on the interviews

5.1.3.1 Development managers

The development managers were very aware of the need to adopt a customer-facing profile, with one manager espousing an extreme view of product and service quality (IREF220). There was very little concern with technological issues, such as CASE tools and there was a general recognition that better methods were unlikely to provide a solution. Associated with scepticism concerning methods was a belief in the importance of getting the right people involved in systems development (IREF040, IREF080, IREF090). Support for the development managers' concern for getting the right people is found in the software engineering literature. Curtis (1992) has reported Boehm's findings that:

> a project staffed with uniformly very low rated personnel on all capability and experience factors would require 10.53 times as much effort to complete the project as would a project team with the highest rating in all the above factors. (Boehm 1981, p. 431)

Category	sub-category	source	group	description
customer/supplier	customer relationships	IREF300	project leader	successful projects are typified by close contact with the customer during the development process
	customer relationships	IREF100	development manager	good quality systems are characterized 100% by good relationships with customers (and converse). Prototypes, project contracts and good communications help build/formalize the relationship
	customer relationships	IREF240	development manager	users and developers may perceive a situation differently, e.g., users categorize change requests as errors while the developers categorize them as enhancements
	service	IREF220	development manager	product quality is almost irrelevant unless there is good service quality. Customers can differentiate between product and service quality
	service	IREF230	development manager	quality is lost through a lack of emphasis on customer service
product	customer expectations	IREF060	development manager	customer expectations can be raised too high (e.g., the prototype has a GUI but the production version runs on a mainframe terminal)
	patterns of use	IREF180	development manager	small organizations using a package proven by larger organizations may discover new problems and perceive quality to be low
	superficiality	IREF270	development manager	when users evaluate software they cannot necessarily see the deep complexity that lies behind the user interface until they have used the software for some time. Superficial aspects, such as whether or not the boxes on the screen have shading, might be a deciding factor when choosing between alternative solutions

Table 5.3: interview findings

category	sub-category	source	group	description
socio-political	attitude	IREF260	development manager	quality depends on user attitudes, beliefs, the way they run the system
	benefit identification	IREF360	development manager	because there is little quantification of benefits at the system development or change level the allocation of resource is ad hoc and susceptible to political factors
	inter-site conflict	IREF280	development manager	allocation of resource to change requests might be a factor where there are multi-site users. The more powerful/influential users might get their requirements satisfied at the expense of other users who are not so well represented
	inter-site conflict	IREF250	development manager	conflict between the Brough, Warton and Farnborough sites
	defensive culture	IREF365	development manager	if customers were asked whether they are satisfied with the current system many would say 'no' as to say 'yes' might lead to effort being diverted to other systems
	project authorization	IREF120, IREF070	development manager	there is little formal investment appraisal at the individual project level. Projects can be justified by 'competitive edge', 'capability', 'basic need to do job'. Many projects are justified within a larger technology plan where financial aspects are considered at a higher level of the organization

Table 5.3: interview findings (continued)

category	sub-category	source	group	description
process	changes in specification	IREF040, IREF160	development manager	inability to meet changing specifications during the system development cycle
	design	IREF205	development manager	developers get lost in the detail design and do not spend enough time on the overall structure of the system (which would make the system more flexible)
	development and use	IREF150	development manager	experience of the development process colours the users' perception of quality in use
	methods	IREF320	project leader	reliability and maintainability (enhanced through the use of methodologies and good documentation)
	methods	IREF290	development manager	SSADM is not suitable for CAD/CAM applications
	timeliness	IREF210	development manager	the elapsed time taken to develop IT applications is too long
	timeliness	IREF030, IREF130	development manager	the application may be redundant by the time it is made available
	requirements engineering	IREF200	development manager	users cannot communicate their requirements clearly and hence prototypes need to be built (this is particularly true of CAD/CAM applications)
	requirements engineering	IREF310	project leader	better requirements definition is needed (e.g., the Esprit F3 project - 'from fuzzy to formal')

Table 5.3: interview findings (continued)

category	sub-category	source	group	description
process	personnel	IREF140	development manager	new staff lacking experience
	personnel	IREF080	development manager	reduction in staff numbers through non-replacement, redeployment, severance packages (regardless of age). As there is a policy of no enforced redundancies it is possible that the staff who leave are 'self-selecting'
	personnel	IREF090	development manager	it is difficult to get project leaders who are technically able and customer aware
	project management	IREF110	development manager	PRINCE is not suitable for small projects
technology	packages	IREF265	development manager	packages are perceived by users differently from in-house developments - in-house systems must be adapted to the way the users work; with package systems users will adapt working practice if necessary
	packages	IREF170, IREF190	development manager	much of the software is bought in and then modified. This together with the long operational life of some systems (15 years is not uncommon) means that much development activity is aimed at supplying the user with a service
	technical environment	IREF050	development manager	do users have a PC with 8 MB of RAM as needed to run the new system?
	technology	IREF020	development manager	rate of spread and change of technology makes management difficult

Table 5.3: interview findings (continued)

Curtis also refers to Vallett & McGarry's (1989) analysis of ten years of data collected in the NASA Software Engineering Laboratory where they found differences of 20+ to 1 in the productivity of individuals.

5.1.3.2 Project managers

The project leaders' concerns related more closely to the supplier view of quality and concern with service and communications tended to relate to the development organization's process capability rather than the actual use of the system. At the project leader level customer support was largely reactive. Although they would not go so far as to say that a low number of change requests indicates a happy customer, the project leaders did assume that the customer was not *un*happy - the "no news is good news" school of customer management. Of course, a low number of requests might indicate low usage resulting from an unsatisfactory application while a high number of requests might indicate a system that is being used heavily, perhaps in unplanned ways. The project managers justified the reactive approach to ongoing support through budgetary constraints and the demands of current work.

Clearly there is a potential mismatch between the desires of the development manager for a service orientation and a system development department organized around a process view of software development, especially as the process view is institutionalized in the organization structure, the budgeting process, the prospects for career advancement, and so on. This mismatch is also highlighted by the narrow range of issues raised by project leaders in the interviews.

5.1.3.3 General issues

A number of initiatives have been undertaken to assess the quality of the IT applications supplied within CAE & Technical. Technical Computing carried out a questionnaire survey of user satisfaction in 1989 and again in 1992 The questionnaire spans five pages and covers background on the types of user, ease of use, and technical quality. CAE Systems have also carried out a customer satisfaction survey and the Software Quality Group is creating a general purpose customer satisfaction questionnaire. In a TQM environment the results of the questionnaires should be expected to form an input to process improvement - at the time of writing there was no evidence that the questionnaires were being used as part of a process of continuous improvement and customer service.

There appeared to be little formal investment appraisal at the individual project level. Projects can be justified by 'competitive edge', 'capability', 'basic need to do job' (IREF120). Many projects are justified within a larger technology plan where financial aspects are considered at a higher level of the organization (IREF070). The organization would benefit from giving more thought to the assessment of IT investments (Farbey et al. 1992, 1993; Willcocks 1992), including a post implementation review that checks to see whether the envisaged benefits materialized and what unplanned benefits and disbenefits arose. As with the customer satisfaction survey, the cycle of continuous improvement and learning does not seem to be completed.

Packages are perceived by users differently from in-house developments - in-house systems must be adapted to the way the users work; with package systems users will adapt working practice if necessary (IREF265) . Much of the software is bought in and then modified. This together with the long operational life of some systems (e.g., 15 years) means that much development activity is aimed at supplying the user with a service (IREF170, IREF190).

5.1.4 Summary of system development interviews

In phase 1 of the project an understanding of the system development environment in CAE & Technical was acquired through interviewing. The interviews highlighted the process-centred perspective of system developers and gave an indication of the difficulties development managers will face in adopting a quality and customer-centred approach to IT. The aim of phase 2 was to understand better the context in which IT applications are used and to identify the implications for customer satisfaction and quality.

5.2 Phase 2: case studies of computer system use

The computer systems chosen for investigation in phase 2 were BCAPE and DQIS. BCAPE - BAe Computer Aided Production Electrical - is used to plan electrical systems for aircraft. DQIS - Design Quality Information System - is used to automate the checking of drawings. Checklists are entered into a computer system and stored in a database from which various analyses and reports are produced.

An introductory meeting was held for each of the applications. In the event effort was focused on BCAPE and, to a lesser extent, DQIS, with both case studies running in parallel. The interviews conducted are shown in table 5.4. In addition to conducting interviews a workshop was conducted for the BCAPE system to bring users and other stakeholders together in order to learn more about issues associated with the system through a process of stakeholder interaction. This form of data collection represents a mild form of intervention.

date	area	role
18/11/93	BCAPE	Head of CAE
22/11/93	BCAPE	Project leader BCAPE development & support
26/11/93	BCAPE	Section leader electrical planning - EFA
26/11/93	DQIS	Design Quality Group - Design Office
03/12/93	DQIS	Section leader responsible for DQIS
03/12/93	BCAPE	Electrical Planner - EFA
15/12/93	DQIS	Head of Design Office
14/01/94	NCC	Review of NCC work and metrics club
26/01/94	BCAPE	Section leader Electrical Planning - Woodford
04/02/94	BCAPE	Electrical Planning manager - Brough
25/02/94	BCAPE	Manger, Manufacturing Engineering - Dunsfold
09/03/94	BCAPE	Shop floor - loom assembly and fitting (EFA)
09/03/94	BCAPE	Shop floor - workshop (EFA)
15/03/94	BCAPE	BCAWD support in Design Office
23/03/94	Systems Comp	Software Manager EFA
23/03/94	Systems Comp	AI applications
23/04/94	Systems Comp	Review of GHOST initiative
06/04/94	DQIS	Senior designer in Design Office
06/04/94	DQIS	Senior designer/checker in Design Office

Table 5.4: interview schedule for phase 2

5.2.1 BCAPE case study

BCAPE (BAe Computer Aided Production Electrical) together with BCAWD (BAe Computer Aided Wiring Design) form a combined graphics and database tool for the design and planning of electrical circuits. The circuits group in the Technical Directorate use BCAWD to design electrical circuits. Data from BCAWD is transferred automatically into a BCAPE database where electrical planners (Production Directorate) then add planning data. The textual output from BCAPE together with graphical output from BCAWD is passed to the shop floor who install looms into aircraft and build electrical panels (figure 5.3).

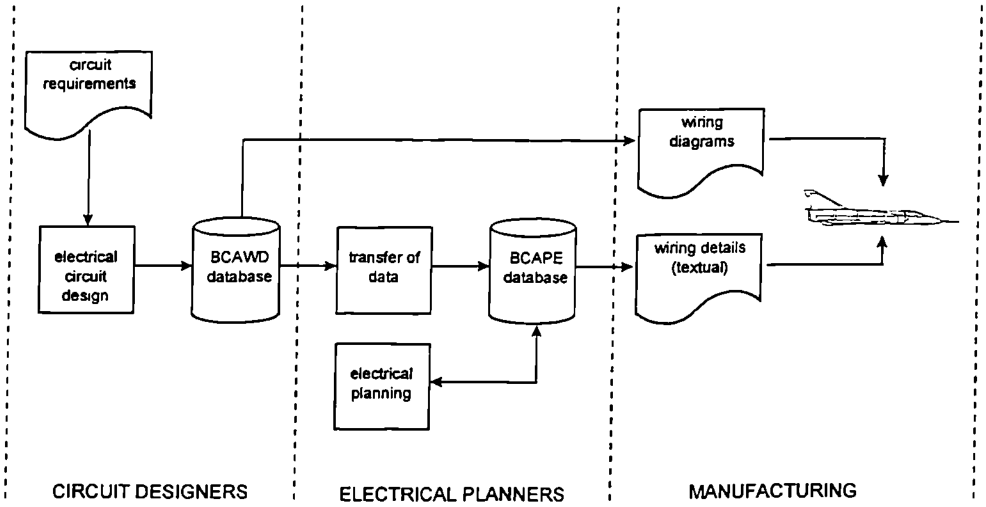


Figure 5.3: the BCAWD/BCAPE systems

BCAPE is supported by Technical Computing, which is part of CAE & Technical Computing (figure 5.2), with staff being situated at Warton and at Filton. BCAWD is developed by a separate team at Farnborough. BCAPE is a large and complex product written in COBOL and FORTRAN with a smattering of Assembler. Development began in 1982 and BCAPE now consists of something in the region of 2 million lines of code.

The environment is which BCAPE is operated is a particularly rich one for an investigation of IS quality, being:

- used at a number of sites;
- used for military and civil aircraft;
- used for production aircraft and development aircraft;
- part of a larger process that includes design and manufacturing involving considerable cross-organizational working;
- business critical;
- mandatory.

5.2.2 Summary of findings - BCAPE

Most interviews were of 2 to 3 hours duration resulting in a lot of data being collected and consequently a considerable volume of written-up interview notes. This data has of necessity been distilled into a usable form by the author.

5.2.2.1 Electrical planning

BCAPE is central to the electrical planning activity and is therefore subject to continuous and extensive use by electrical planners. The planners reported that the user interface was very poor, that documentation and user procedures were largely absent, and that training was entirely "on the job". A number of interviewees commented that it takes at least a year to become a competent user of BCAPE. When BCAPE is used for production aircraft with long periods of stability user satisfaction was notably higher. Where it is used for development work (e.g., European Fighter Aircraft - EFA) then the need for shortened cycle times caused considerable problems, resulting in the addition of manual procedures and ad hoc work-arounds.

Data inconsistencies were reported between BCAPE and BCAWD, a problem that is caused by the transfer and duplication of data between the design and planning systems. This issue is compounded by BCAPE and BCAWD being developed and maintained by different parts of the organization, but should be resolved through the development of a single BCAWD/BCAPE database. Difficulties were experienced at Woodford, which is a civil site, relating to the conversion and loading of data when converting to BCAPE. This resulted in a very low satisfaction score for the introduction phase, but a high expectation of the benefits that would be realized following successful implementation. There was general agreement that the level of support from Technical Computing was very high. It was noted that there is no financial recharge made for BCAPE costs. Perhaps a chargeout process would help institute a customer/supplier relationship whereby users of BCAPE would be concerned with value for money and thus with alternatives to BCAPE.

A common thread in the case study was the lack of 3D visualization in BCAPE. It was suggested that the 3D CAD system CATIA might be able to provide this facility, but concerns were raised that CATIA would not handle the complex issues of electrical planning, such as "effectivities" of wiring changes, and the sophisticated checking of which BCAPE is capable. There was a general feeling from the electrical planners that BAe management do not understand the complexity of BCAPE and the complexity of the work that it supports.

5.2.2.2 Manufacturing

Manufacturing take textual output from BCAPE and use it to wire and install a loom in an aircraft and for electrical panels. Shop floor electricians found the textual output very difficult to work with and spent a lot of time pulling series 2 drawings from BCAWD to make up for the shortcomings of the text-only output from BCAPE. In practice electricians sometimes make their own sketches before wiring a panel. Often they need to pull a number of series 2 drawings before they can begin wiring, resulting in a number of days being spent in preparing all the documentation needed to wire a panel. 3D output (or even 2D) would help reduce the set-up time for wiring. The electricians want to supplement rather than replace the textual output of BCAPE - the textual output is useful for showing connection details and as a sign-off stub (audit trail). In some cases electricians have worked directly from BCAWD output. However, this requires that the electrician is familiar with the panels and therefore relies on the knowledge in the electrician's head (i.e., it is only possible to work from BCAWD output if the electrician is experienced and is wiring a panel that has been done before - the electrician is in effect doing a combined planning and installation activity).

Given the need for short cycles on EFA the electricians are often working from BCAPE output plus manual reworks, with the formal documentation catching up some weeks later. A planning process centred on BCAPE can cope with production aircraft but has too slow a cycle time for development purposes. Considerable effort was expended in keeping all the paperwork uptodate in a situation in which standard procedures were being flexed.

5.2.2.3 Design office

The circuit designers are up-stream of BCAPE and can be typified as a supplier rather than as a customer. As noted above, it is possible for experienced electricians to work from BCAWD output; the feeling in the design office is that BCAPE and BCAWD could be combined and design and planning functions merged. For example, one approach would be to use CATIA for 3D visualization and for recording planning details. However, there is a considerable difference in the culture of the design office and the production areas - such an organization change would run an increased risk of failure if it were based upon a technological perspective and Beatty & Gordon (1988) and Liker et al. (1992) have highlighted some of the problems of integrating design and manufacturing through the introduction of CAD/CAM.

5.2.3 Implications - BCAPE

The primary customer for BCAPE, as far as the system developers are concerned, is electrical planning. These are the people who enter data directly to BCAPE and use the system to support their primary activity. However, in the wider context a more suitable choice of primary customer is manufacturing - they use the BCAPE output to implement electrical circuits. With respect to the organization we might ask:

- can manufacturing carry out their activity effectively using BCAPE output?
- is the process that BCAPE supports organized appropriately?

Although manufacturing are not a primary user of BCAPE (they take the output but only have limited computer terminal access and do not enter any data to BCAPE) they need to be treated as a customer of BCAPE as well as a customer of electrical planning. The systems developers support the electrical planners, who are fairly happy with BCAPE since it allows them to get their job done. Manufacturing use the output from BCAPE and are rather less satisfied with it. The reputation of BCAPE continues to be tarnished by the poor reports that rise through the manufacturing organizational reporting structure, while the story from the system developers and electrical planners is that BCAPE is an adequate system. The system developers only have formal access to electrical planners and have to rely upon the planners to understand the needs of the design (up-stream) and manufacturing (down-stream) groups. The system developers get manufacturing's requirements second-hand as interpreted by the planners and are in a difficult position if they wish to improve the organizational effectiveness and reputation of BCAPE. There is a

BCAPE user group, but Manufacturing are not represented on it - they expressed resentment at not being involved in the development of BCAPE.

With respect to process organization, it is clear that IS quality is achieved in a larger context than that of primary computer system users. One way of addressing the difficulties of the separation of design engineering, and manufacturing would be to make organizational changes. This might involve manufacturing sign-off of design, the introduction of an integrator, cross-functional teams, through to a product-process design department (Dean & Susman (1989) identify four different ways of combining design and manufacturing). However, system developers provide a computer system - they are often not in a position to initiate changes to the structure of the organization.

In conclusion, system developers can and should be responsible for software quality but they cannot necessarily address issues of IS quality where organizational boundaries and processes are crossed. Developers find it more difficult still to initiate organizational change for process improvement. What, then, is the role of system developers? System developers might concentrate on a process perspective and focus on the provision of computer systems with software quality. At the other extreme they could operate as business process analysts addressing issues of organizational change supported by IT. In practice they probably end up sitting uncomfortably somewhere in the middle as illustrated by the BCAPE case study.

5.2.4 Design Quality Information System - DQIS

DQIS is used in the design office to monitor the quality of drawings through the capture of checklists into a database. DQIS went live in October 1992 and was built by Enabling Technology (see figure 5.2) using ADABAS/Natural running on an IBM mainframe. DQIS is used to monitor and through the provision of feedback to improve the quality of drawings. Given the data-intensive nature of DQIS, the quality of DQIS as an information system depends partly upon the completeness, timeliness, and accuracy of the data contained in the DQIS database. As to whether appropriate data is captured and held in DQIS depends upon what purpose the data is intended to support. Currently a mass inspection approach is adopted whereby every drawing is checked against a checklist. Reports from DQIS are concerned with the "cost of quality", which is quantified in terms of the level of re-work. Quarterly reports are produced in full with monthly subsets. The results from DQIS are used in team meetings as part of a quality improvement process.

Attributes of DQIS include:

- it is used in one department and has very low visibility outside of that department (multiple sites use DQIS, but they all use it in the drawing office);
- it is not business critical - drawings can be made and released regardless of DQIS;
- there are no automated feeds into or out of DQIS;
- it does not impact stakeholders significantly (yet).

5.2.5 Summary of findings - DQIS

The primary users of DQIS are the Design Quality Group (DQG), a small team responsible within the design office for design quality in general and the administration of DQIS in particular. The main parties affected by DQIS are the designers and the checkers. There have been organizational changes that have resulted in a move from functional management structures (e.g., design, engineering, etc.) to project-based organization (e.g., Tornado, EFA, etc.). Releases of drawings are made via DPDS, although there is no automatic interface from DQIS to DPDS. The three main roles in the design office appear to be designing, checking, and liaison - one person might take on all three roles at the same time (note that all checkers are designers).

5.2.5.1 Design Quality Group (DQG)

DQG is the primary user of DQIS. DQG personnel use DQIS on an everyday basis and are very familiar with the product, to the extent that they can develop additional reports themselves using 4GL facilities. Although they would like a graphical user interface and PC facilities (these should be available in the near future) overall they reported a high product quality. Also, given how closely DQIS fits the role of the DQG there is a high degree of process quality. The DQG reported very high satisfaction with the service provided by the developers.

5.2.5.2 Designers

Checklists do not need to specify the individual designer who made the drawing. There is little feedback on the severity of an error; some errors are trivial, some are "real" and will affect assembly (for example, a component might not fit into an aircraft). Sensitivity to the severity of error types is needed if quality is to be improved in a targeted way. Designers are secondary users - they do not key the checklists into DQIS themselves.

5.2.5.3 Checkers

Checkers are senior designers and are primary users of DQIS. Keying a checklist is not an onerous task - it was reported that it took 5 minutes. One benefit of DQIS is that a feedback loop is established whereby design quality is improved. Categorizing of errors helps to focus effort. The main aim is to reduce the number of query notes (QNs).

5.2.6 Implications - DQIS

The culture of the design office is to not single individuals out. DQIS is used as a broad-brush tool to make general improvements to the quality of drawings, with quality being measured in terms of re-work. There are indications of a move towards self-checking. A proposal for consideration is that designers could complete checklists themselves and each group then take full responsibility for the quality of the drawings that they produce. So far, the output from DQIS does not seem to have been used to make organizational changes; the process of drawing production is largely unchanged although more data is available about that process. Because there is not a significant impact on the organization or on the individual designers/checkers the author got the feeling that the output from DQIS is viewed neutrally. DQIS output is used in the project groups to agree how the quality of drawings can be improved, but given that this is a three-monthly cycle it does not appear to pose any short term threat to designing/checking. If DQIS output were to be used to justify organizational changes, to assess individuals (e.g., performance-related pay) the author would expect there to be considerable interest in what data is collected and the purposes to which it might be put.

5.2.7 Summary

The two case studies, BCAPE and DQIS, were very different. BCAPE is an old system that spans functional and organizational boundaries; it is a core system in the manufacture and maintenance of aircraft. The flow from circuit designers to electrical planners to shop-floor electricians spans three very different and distinct organizational cultures. The divisions between the groups were encapsulated in an A4 poster that the author noticed on the wall of the shop-floor during an interview. This poster is reproduced in figure 5.4.

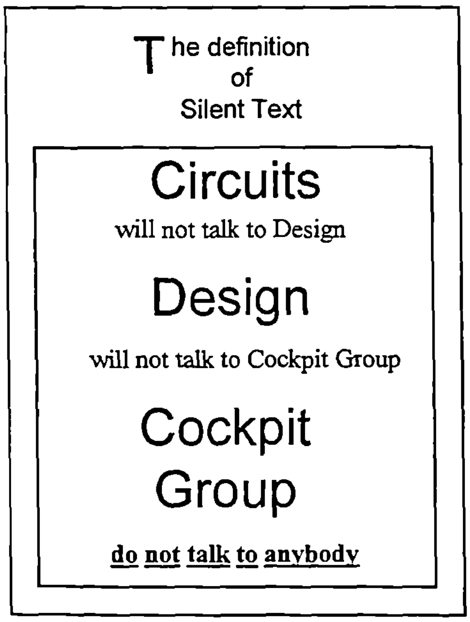


Figure 5.4: poster from the shop-floor

Silent text refers to details held on the BCAPE database, such as forthcoming changes, but not printed out on the series 2 diagrams (which are not produced from BCAPE). The difficulties of getting all the data needed on the shop floor to wire an aircraft and the organizational barriers to doing so are neatly encapsulated in figure 5.4. By contrast, DQIS was being used in a mono-culture, the design office, was not an essential part of the production process, and did not seem to have a great affect on the stakeholders. With DQIS it might be appropriate to adopt a predominantly T approach to IS development, but with BCAPE it is difficult to see how a T perspective, even with highly competent developers and a rigorous engineering process, will be sufficient to address and surmount the organizational (social and political) issues.

5.3 The provisional form of the ISDM/Q

The second phase of the fieldwork highlights the need to consider the organizational setting (for example, with BCAPE the cultural and organizational issues of design, planning, and manufacturing), the technical artefacts (for example, BCAPE had performance problems resulting in 8 hour batch runs), and the work aspects (for example, it takes a year to learn to use BCAPE). This empirical research together with the framework developed in chapter 4 have resulted in the author recognizing a need to consider:

- organizational quality;
- socio-technical (work-life) quality;
- technical artefact quality.

The Multiview methodology, which addresses these three areas, (Avison & Wood-Harper 1990; Wood-Harper & Avison 1992) is used as the basis for the ISDM element of the ISDM/Q and quality function deployment (QFD) will be used to provide the Q element. The form of Multiview adopted for the action research is shown in figure 5.5, with QFD being placed at the centre. Significant differences between the ISDM proposed here and Multiview are:

- stakeholder analysis has been introduced to complement SSM and the Multiview "human activity" module renamed "analysis of organization";
- structured methods have been replaced with Object-Oriented analysis and the Multiview "information analysis" module renamed "process modelling";
- the range of socio-technical options has been extended.

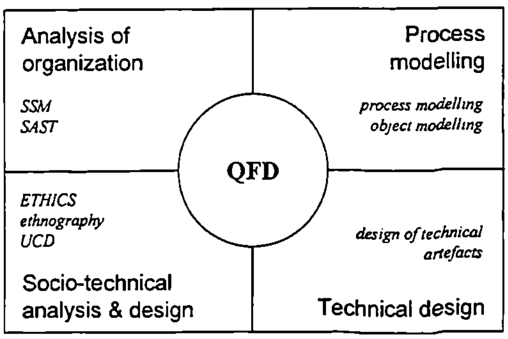


Figure 5.5: overview of the quality approach to IS development (ISDM/Q)

The IS quality outcomes in chapter 4 consisted of organizational, work-life, and technical artefact quality. The fourth module in the ISDM/Q, process modelling, can be thought of as a bridge between the organizational world of activity and the technical world of computer system design. Process modelling aids the enactment of the organizational vision by providing a basis for the design of technical artefacts (T) and also provides a means for the re-vision to be communicated (O). It points in both directions and does not of necessity imply the construction of technical artefacts - however, process modelling in itself is not a quality outcome unless it results in changes to organization, work or technical artefacts.

The principal techniques used in the ISDM/Q are now outlined prior to their application being described in chapter 6.

5.3.1 Analysis of organization

In the analysis of organization module the major techniques employed are strategic assumption surfacing and testing (SAST) and SSM.

The reasons for choosing SAST and SSM are that these are powerful methods for addressing pluralism and complexity respectively. Flood & Jackson (1991) argue that SAST depends upon genuine participation for it not to be 'distorted in use' (p. 133) and also argue that although SAST can cope with pluralism it is not suitable for addressing complex situations. In one of their case studies, "Winterton Co-operative Development Agency", Flood & Jackson (1991) describe the use of SAST in conjunction with SSM, the aim of which is to provide an approach suitable for pluralistic/complex situations. A pluralistic situation is one in which there are multiple stakeholders who have a basic compatibility of interest but who do not agree entirely on ends and means and whose values and beliefs will be divergent (Flood & Jackson 1991; Burrell & Morgan 1979). A combination of SSM and stakeholder analysis has been proposed as a basis for defining the quality of an IS (Vidgen 1994).

The use of SAST also reflects an organizational learning approach to IS development that would support a BPR initiative. Argyris & Schön (1978) refer to a learning cycle of discovery, invention, production, and generalization, with double-loop learning catering for the surfacing and challenging of deep-rooted assumptions which were previously unknown or undiscussable. SAST provides a structure and method for participants to surface and test each other's mental models. SSM promotes learning through the development of systemic models that are used to gain insight into a problem situation - it is doubly systemic in the sense that systems ideas are used to inform the learning process itself. The combination of SAST and SSM is thus a powerful approach to systematic and systemic organizational learning, while the utilization of the TQM/QFD techniques of quality requirements gathering and quality planning provide a basis for deploying demanded qualities through the IS development process.

5.3.1.1 Stakeholder analysis (SAST)

Stakeholders will be identified from a rich picture, which has the benefit of giving the analyst a broad understanding of the problem situation. The rich picture is a SSM technique that allows a problem situation to be expressed informally, including relationships and value judgements (Checkland 1990, Lewis 1992). Rich pictures are helpful in gaining an understanding of a situation and provide an IS development team with an starting point for establishing a common understanding. In particular the rich picture is a very useful way of identifying stakeholders (Vidgen 1994). However, it must be remembered that this is not intended to be an objective representation of a problem situation; in preparing a rich picture the analyst is making an interpretation. Consequently there is no single correct rich picture and in one sense a "good" rich picture is one that people recognize as being representative of the situation they find themselves in.

The rich picture produced as a result of the situational analysis can be used to identify stakeholders and hence customers. Zultner (1990) notes that users of a computer system need to be identified and segmented, possibly on the basis of frequency of system use or whether they are internal or external users. Many groups will have an impact on the development and operation of a computer system, including system developers, IT operations, internal audit, and so on. These groups are all potential customers of a computer system and will have quality requirements. The more general term for these groups of interested parties is "stakeholder".

Stakeholder analysis is a well-established technique which in its evolved form proposes (Mitroff & Linstone 1993):

> Stakeholders are any individual, group, organization, institution that can affect as well as be affected by an individual's, group's, organization's, or institution's policy or policies. (p. 141)

An organization comprises the entire set of relationships it has with itself and its stakeholders (Mitroff & Linstone 1993, p. 142) and as these relationships change over time then so the organization changes, becoming in effect a different entity. This view of organization is sympathetic with that of Vickers' notion of appreciation and a concern with relationship-maintaining and judgement rather than the 'poverty-stricken notion of goal-seeking' (Checkland & Casar 1986). Organizations learn by challenging their deep-rooted assumptions and by developing different strategies that are in dialectical opposition (Mason & Mitroff 1981; Mitroff & Linstone 1993).

Stakeholder analysis is part of Mason & Mitroff's (1981) strategic assumption surfacing and testing (SAST), which comprises the following stages: formation of groups who identify stakeholders; surfacing of assumptions; dialectical debate; and synthesis. In assumption surfacing a rating is made of the assumptions the groups have made about the different stakeholders. Two dimensions are used in the rating: the degree of importance to the intended change, and the level of certainty that the assumption accorded to the stakeholder by the group is justified. The groups then present their positions and engage in debate, following which a synthesis is made through a process of negotiation which may result in a modification of views.

5.3.1.2 Soft Systemic analysis

Conceptual models are models of purposeful human activity that cope with basic business processes as well as abstract and intangible processes. Specifying the logical dependency of activities leads to fluid modelling which is less linear and simplistic than reductionist methods. Levels of resolution allow detailed modelling of sub-systems which nevertheless retain their relation within the whole system. Root definitions (textual definitions of potential systems akin to mission statements) offer a structured way in to the 'visioning' of new processes (Vidgen et al. 1994; Wood et al. 1995). A root definition template is:

A system to do **X**, by (means of) **Y**, in order to **Z**

thus telling us *what* the system will do, *how* it is to be done, and *why* it is being done (the why question relating to longer term aims). The CATWOE expands upon the root definition and is made up of the elements described in table 5.5. In the early stages of analysis it is better to treat the similarity between the traditional customer of quality and the Customer of SSM as coincidental. The customer for quality purposes is just as likely to play the role of an SSM Owner or Actor as it is a Customer.

C	customers	the victims or beneficiaries of T
A	actors	those who would do T
T	transformation process	the conversion of input to output
W	*Weltanschauung*	the worldview that makes this T meaningful in context
O	owners	those who could stop T
E	environmental constraints	elements outside the system which it takes as given

Table 5.5: the SSM CATWOE mnemonic

The use of conceptual models and root definitions, together with the CATWOE mnemonic, encourages reasoned and internally cohesive modelling that encapsulates most of the concepts important in systems thinking. The *Weltanschauung* (worldview) concept encourages consideration of the differing perspectives of stakeholders. The modelling of 'relevant systems' and the clear status of SSM models as 'holons' (logically consistent potentially operable systems, not representations of the real world) offer a rigorous way of structuring thinking about re-conceptualization. The cultural stream of analysis, though not at present so well developed, offers a vehicle for social and political analysis that may be as, or more, crucial to the success of the intervention than consideration of the processes. Much of this analysis serves the purpose of establishing which changes are 'culturally feasible' - a consideration fundamental to successful business quality improvement.

Having constructed a systemic model of human activity a judgement is made concerning how the success of the system in accomplishing the specified transformation can be assessed. Within SSM, three criteria for judging the success of a transformation are utilized: efficacy, efficiency, and effectiveness (Checkland & Scholes 1990) (table 5.6).

Success factor	Description
Efficacy	does the transformation work; will it actually produce the required output
Efficiency	is the transformation being carried out with the minimum resources (i.e., the amount of output divided by the amount of resource used)
Effectiveness	is the transformation process performed by the system meeting the longer term aim (it is possible to be efficient without being effective)

Table 5.6: the 3Es for conceptual model assessment

The '3Es' have been supplemented with elegance and ethicality (Checkland & Scholes 1990) to provide a '5E' basis for the definition and evaluation of quality. Elegance is an assessment of the design of the transformation - is it aesthetically pleasing; is it over complicated; is it over- or under-engineered. Ethicality is concerned with whether the transformation is acceptable from a value judgement perspective, where value judgements concern 'good' and 'bad' and are subject to change over time (Vickers 1965, 1984). Such judgements undoubtedly provide for an orthogonal check to the rationalistic 3Es but Grahn & Bergvall (1994) have criticized Checkland's approach as being too coarse-grain; they propose that the work of de Raadt (1989) be used to provide performance indicators derived from concerns such as faith, love, harmony, and retribution.

At first sight one might think that SSM has not taken account of 'Economics' (luckily, even this begins with an 'E'). With respect to economics, all attempts to improve the quality of a transformation are bounded by the availability of resources and the willingness to commit those resources to improving quality in any given area of organizational activity. Historically, these resources are quantified using a financial unit of measure, which is a metric rather than a quality factor per se. Thus, quality is always constrained by resource availability, a point recognized also in QFD.

The SSM view of the success of a transformation seems to provide a basis for a general and rigorous approach to quality, but one must bear in mind that the

SSM conceptual model is an ideal type which, according to SSM orthodoxy, must not be confused with real world activities. Given the separation of conceptual and real world, what is the status of the 5Es? Certainly they are not qualities demanded by real-world customers. They are quality characteristics that are associated with a successful transformation, in the same way that the ISO9126 standard defines generalized software quality characteristics that are generally accepted and expected to contribute to quality as perceived by the customer. To find out the relative importance of the characteristics, to find out how the characteristics might be associated with customer quality, and to derive a set of criteria and metrics it is necessary to make explicit reference to real customers in a real world. For example, a measure of efficiency for the conceptual system 'transform unpaid supplier compensation requests into settled compensation requests' might be achieved in the real world through the payment of invoices and a suitable measure of efficiency might be the average time taken to pay an invoice, a measure which will be affected by real-world procedures and technologies. Until they are couched in a specific real-world context the 5Es of SSM are as use*ful* and use*less* as software quality characteristics (ISO9126 1991) when considering what constitutes customer satisfaction.

5.3.2 Process modelling

Defined processes play a major role in getting from qualities demanded by the customer to customer satisfaction (satisfied qualities). The process modelling element of the IS quality methodology is concerned with modelling processes and object types and can be thought of as a bridge between the world of customers and demanded qualities and the world of technology. Process modelling is the traditional province of systems analysis, which is typified by structured methods such as SSADM (Structured Systems Analysis and Design Method) and Object-Oriented (OO) methods such as OMT (Object Modelling Technique) of Rumbaugh et al. (1991).

The approach taken here to traditional systems analysis and process modelling is to use the object model of OMT (Rumbaugh et al. 1991) but to supplement it with the event schema, which is a notation for process modelling recommended by (Martin & Odell 1992) in their work on OO analysis (de Carteret

& Vidgen 1995). The reason for doing this is that the event schema gives a process view of systems analysis while retaining an OO approach. Although the process module of the IS quality methodology could be replaced by SSADM it is my belief that an OO approach provides a better basis for process modelling as it is firstly a better fit with the systemic activity modelling performed in the quality requirements module, and secondly a sounder basis for the design of computer systems, particularly with respect to management of software complexity and software reuse.

The Process module consists of two elements: process modelling and object modelling. These are logical models and as such do not contain details of information technology; indeed, there is no requirement for the processes and object types to be implemented using IT at all. These models should be supported by CASE (Computer Aided Software Engineering) tools such as Select SSADM and Select OMT, IEF (Information Engineering Facility).

5.3.2.1 Business process modelling

Event schemas are used to specify processes (Martin & Odell 1992). Rather than using the data-flows and data-stores of data flow diagrams (DFDs), the event schema is a model of operations and events and is therefore more suitable as a basis for implementation via O-O and event-driven software - it is also more meaningful to users as it describes work procedures rather than data flows. Furthermore, DFDs produced in SSADM are used to identify events and functions and then discarded, whereas the event schema provides a basis for physical design.

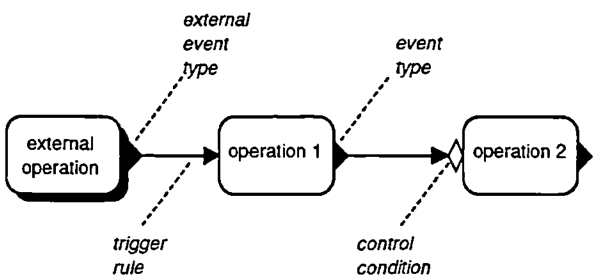


Figure 5.6: event schema notation

In the event schema operations give rise to the occurrence of events that can trigger other operations (figure 5.6). External operations result in external events that trigger internal operations which in turn result in the occurrence of further events. Control conditions specify how the preceding events result in a subsequent operation being triggered. As well as providing a basis for the development of computer systems this form of defined process is also essential to quality assurance certification schemes such as ISO9000. The definition of process models serves two purposes; firstly it points backwards to business requirements for defined processes, and secondly it points forwards to the development of computer systems.

The operations in an event schema are decomposed hierarchically until they are at a sufficient level of detail to be described in half a page of text, or by a simple flow chart, decision table, or similar technique. These primitive operations should form the procedures manual for a business unit regardless of whether or not the operations are subsequently automated. It is the primitive operations that act upon the business objects in the computer system (see de Carteret & Vidgen (1995) for further description of event schemas and object models and their interaction). The object types that processes act upon are represented using an object model.

5.3.2.2 Business object modelling

The object model represents the types of data that are of interest to an organization. In the object model example in figure 5.7, object types of interest include InterestedParty and Property. Purchaser and Vendor are specializations of InterestedParty, as denoted by the triangle symbol, and will inherit all the properties (attributes and associations) of InterestedParty. Property is an aggregation of one or more rooms and may include a garage and a garden. The association between a vendor and a property is one to many - a property must have one and only one vendor; a vendor may offer many properties. The association between purchasers and properties is many to many. In the relational model this requires a resolving entity, but in the object model it is possible to attach attributes to the association (in this case offerAmount and offerDate). Further details of the object model notation are given by Rumbaugh et al. (1991).

Instances of an object type must be in a defined state. For example, an offer might be in the state pending, accepted, or rejected. A state transition diagram should be produced for each of the object types to show the different states that an object may be in and to show the valid state changes (transitions). This analysis shows how objects change state over time in response to business events, providing a dynamic view of the computer system that complements the process view of the event-schema and the data view of the object model. Methods to support the state transitions can then be added to the object types.

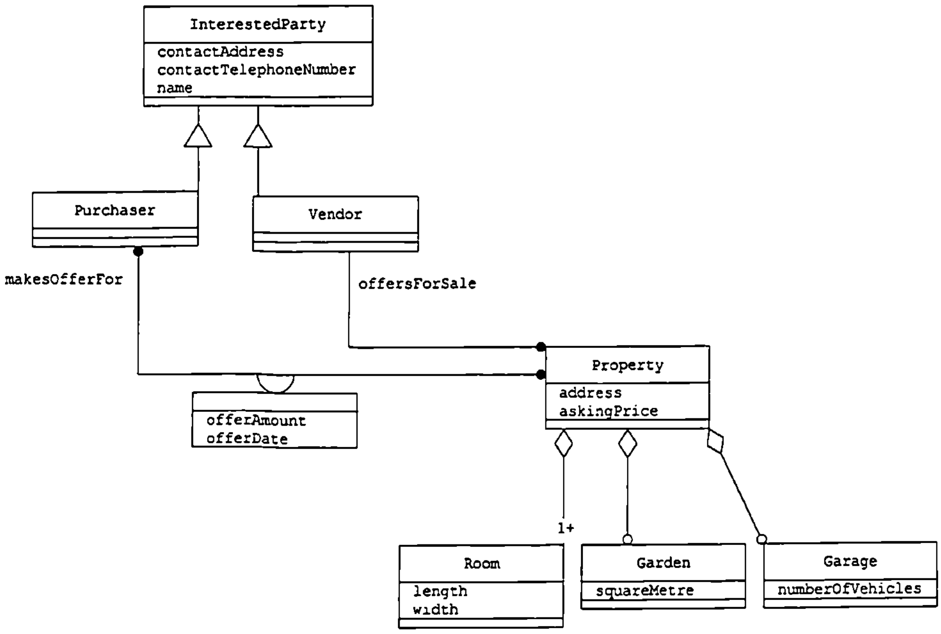


Figure 5.7: object model

5.3.2.3 Summary

The Process module of the ISDM/Q defines processes and data requirements and is the province of traditional systems analysis (whether it be structured methods or OO Analysis): the aim is to develop a logical model of what is to be done. The process and data models are a bridge used to:

- enact the vision of purposeful activity created in the analysis of organization module of the ISDM/Q through the specification of processes and data requirements;
- establish defined processes that provide a basis for performance assessment;
- provide a specification for the development of (computer-based) technical artefacts.

The next section considers the interests of those whose job might be affected by changes in processes and the introduction of new computer systems.

5.3.3 Socio-technical analysis and design

In chapter 2 different approaches to socio-technical analysis and design were identified. One of the best known approaches Mumford's ETHICS, which is the method recommended in the Multiview methodology (Avison & Wood-Harper 1990). The IS developer might adopt Ken Eason's user-centred design (UCD), which although broader in scope and more specific about the use of technology does not provide the detailed guidance of ETHICS. The developer might also adopt an ethnographic stance and study how the work that is to be redesigned and supported by computer systems is actually achieved (Randall et al. 1994). Since the approach adopted in the action research was limited to observation these approaches are not described in further detail here.

5.3.4 Design of technical artefacts

The aim of technical design is to bridge between the process modelling module and the construction of technical artefacts. In structured approaches, such as SSADM, the design involves a detailed logical system specification which is followed by physical design taking into account the specific technologies to be employed. In OO design it is claimed that there is less of a gap between analysis and design since the same paradigm is used in both (Martin & Odell 1992; Coad & Yourdon 1991b). The design and construction of technical artefacts was outside of the scope of the action research and therefore the techniques of technical design are not described in any further detail.

5.3.5 Quality function deployment

The four analysis and design modules are integrated by QFD. Matrix A1 is the cornerstone of QFD and is used to relate qualities demanded by customers to characteristics of a product or service. As noted in chapter 2, the use of matrix A1 is a narrow view of QFD - for the full benefits to be achieved customer demanded qualities must be deployed through all phases of product development and manufacturing.

5.3.5.1 Quality planning

Once the voice of the customer has been collected a quality plan is produced. An example of a quality plan is shown in figure 5.8. This quality plan concerns a pencil and although simplistic it demonstrates the mechanics of quality planning (the derivation of the quality plan columns is described in table 5.7).

Matrix A1

Demanded qualities	rate of importance	company now	competitor x	competitor y	plan	ratio of improvement	sales point	absolute weight	demanded weight
	Quality plan								
Easy to hold	3	4	3	3	4	1.00	1	3	14
Does not smear	4	5	4	5	5	1.00	1.2	4.8	23
Point lasts	5	4	5	3	5	1.25	1.5	9.375	44
Does not roll	3	3	3	3	4	1.33	1	4	19
						Total		21.2	100

Figure 5.8: an illustration of a quality plan (King 1989)

In completing the quality plan it is necessary to get the customer's priority for each of the demanded qualities.

Column	derivation
rate of importance	a 1 to 5 scale (1 is least important, 5 most important).
Company now	where the company is now on a scale of 1 to 5 (1 is very poor, 5 is excellent)
competitors	how competitors perform on each of the qualities on a scale of 1 to 5
company plan	determined by looking at where the company is today in relation to competitors and the customer's importance rating - it should also take into account the organization's strategic plan
improvement ratio	calculated by dividing the company plan by company now
sales point	sales points are used to increase the weight of qualities that are considered to be important in the market place (to be used judiciously)
absolute quality weight	calculated by multiplying the rate of importance by the improvement ratio by the sales point
demanded quality weight	calculated by converting the absolute quality weight into a percentage (for each quality: absolute quality weight divided by total of absolute quality weights)

Table 5.7: columns of the quality plan

5.3.5.2 Matrix A1

The primary matrix in QFD is known as matrix 'A1'. This matrix is used to deploy demanded qualities into quality characteristics. An illustration of matrix A1 is given in figure 5.9, which develops further the simple scenario for a pencil introduced in figure 5.8. A quality characteristic is the supplier's view of how they will satisfy customers' quality demands. For example, the customer demands a pencil that does not smear; the characteristics of a pencil that the supplier believes will satisfy this requirement are time between sharpening and the amount of lead dust generated. By inspection of figure 5.9 one can see that there is a many to many relationship between demanded qualities and quality characteristics - it is not a simple matter of assigning a single characteristic to each quality. The strength of the linkages between qualities and characteristics is given as "strong", "some", and "possible".

The basic assumption of QFD is that if the supplier can measure, control, manage, and improve the quality characteristics, then the demanded qualities will be met and customer satisfaction will increase. It is therefore important to identify appropriate qualities (the customer's view), relevant characteristics (the supplier's view), and to understand the relationships between qualities and characteristics.

Matrix A1

		Quality characteristics				
Demanded qualities	demanded weight	length	time between sharpening	lead dust generated	hexagonality	
Easy to hold	14	O			O	
Does not smear	23		O	+		
Point lasts	44	^	+	O		
Does not roll	19	^			+	
total		105	465	339	213	1122
percent		9	41	30	19	100
company now		5"	3pgs	3g	70%	
competitor x		5"	5pgs	4g	80%	
competitor y		4"	2.5	3g	60%	
plan		5.5"	6pgs	2g	80%	

+	strong correlation (weight 9)
O	some correlation (weight 3)
^	possible correlation (weight 1)

Figure 5.9: illustration of matrix A1 (King 1989)

The importance of a quality characteristic is dependent upon the relationships that the characteristic has with demanded qualities, taking into account the importance of the quality and the strength of the relationship. For example, the characteristic 'time between sharpening' has a calculated weight of:

$$(23 * 3) + (44 * 9) = 465$$

The weights of the characteristic are then normalized into percentages. Inspection of figure 5.9 shows that the characteristics 'time between sharpening' and 'amount of lead dust generated' are most important. Characteristics must be assessable and wherever possible should be measurable. For example, the 'time between sharpening' is measured in number of pages, with a current value of 3 and a planned value of 6.

5.3.5.3 Interaction analysis

A further analysis that is common to all stages of QFD is to perform an interaction analysis. This is concerned with building an understanding of how characteristics interact with each other. For example, in software quality it is recognized that maintainability and efficiency are usually inversely related. To perform an interaction analysis, a matrix is created with the same characteristics in the rows and columns, with the diagonal and duplicate combinations hatched out. Correlations between characteristics are recorded symbolically as strong positive, positive, negative, and strong negative. This analysis is often performed manually in the 'roof' of matrix A1 (this why the QFD matrices are often known as the 'house of quality'). An interaction analysis is useful as it can show situations in which action to improve one characteristic is likely to lead to a deterioration in another characteristic(s). It is also helpful to know where characteristics are positively correlated since improvement programmes can then be scoped and better targeted.

5.3.5.4 Deployment

Quality characteristics are measurable attributes of the product or service. Matrix A1 should not contain parts of the product, functions of the product (what it does), or how it is manufactured or delivered. In its simplest form QFD contains four phases (figure 5.10). The Goal/QPC version of QFD (King 1989) uses a 'matrix of matrices' containing 24 individual matrices catering for a range of deployments that include cost, mechanisms, functions, failure modes, new concepts, and breakthrough analyses. The matrices are numbered A to F in columns and 1 to 4 in rows. Matrix

A1 is at the top left hand corner and is the basis from which all the other matrices are derived. Japanese QFD practitioners (Akao 1988) stress the importance of designing a specific network of matrices to suit each application of QFD. Although software is available to support the QFD process there is a danger that the analyst will focus on the standard matrices rather than on the distinguishing aspects of the situation and the products to which QFD is to be applied. In this respect the use of QFD is contingent and sympathetic to Multiview and SSM. Experienced analysts take a similar approach to structured methods, such as SSADM - it is important not to mistake the map for the terrain.

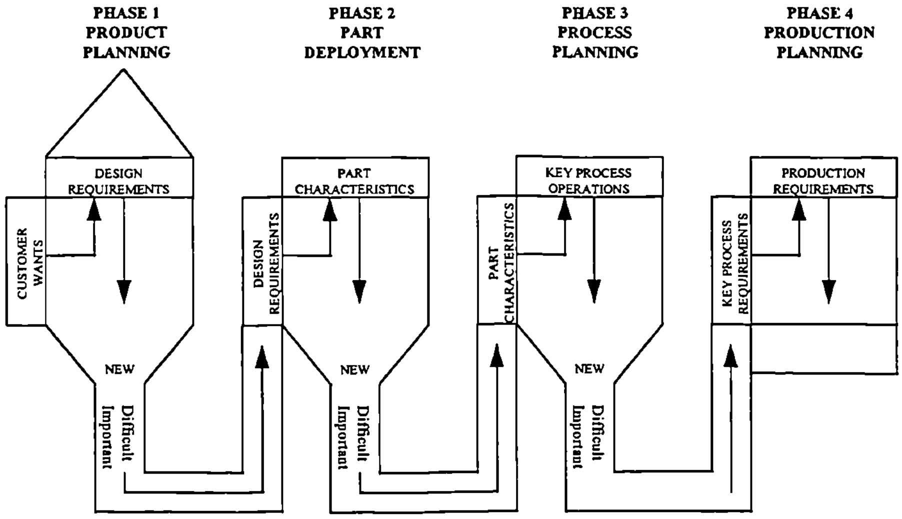


Figure 5.10: the four phases of QFD for manufacturing industries

Chapter summary

The fieldwork has lead to an understanding of the organizational context in which developers and users are working. Although development managers might wish to adopt a service approach and a closer alignment with business needs, the developers appear to be working within a supplier-focused and engineering-based tradition. The case studies highlighted that developers can be rendered powerless by organizational aspects such that the T perspective to the design and use of computer-based technical artefacts is overwhelmed by the context. If a greater competence in organizational change is needed then this raises the issue of the role of the IS developer and the place of the IS development in the organization. Multiview, with specified modifications, has been used as a basis for the ISDM element of the ISDM/Q and quality function deployment (QFD) has been chosen to provide the Q element of the ISDM/Q. The primary techniques of the ISDM/Q were described as a prelude to applying the provisional form of the ISDM/Q via action research. These experiences are reported in chapter 6 and the evolved form of the ISDM/Q is described in chapter 7.

6

Applying the ISDM/Q

Introduction

In chapter 4 an IS quality framework was presented and in chapter 5 the first two phases of the fieldwork were described and a quality approach to IS development (ISDM/Q) proposed. In this chapter the experiences of applying the ISDM/Q in action research are described. Reflections on the methodology (M) and the area of application (A) are made in chapter 7 and the evolved form of the ISDM/Q that came out of the action research is presented. Learning that arose about the framework (F) and IS development is presented in chapter 8.

For the purposes of description, this chapter is organized around the ISDM/Q modules as described in chapter 5 (figure 5.5):

1. analysis of organization;
2. quality function deployment;
3. process modelling;

4. socio-technical analysis and design;
5. technical design.

Although the application of the ISDM/Q is described in the above sequence this is done in the interest of creating a coherent narrative, since much of the work was conducted in parallel. The situation in which the action research was conducted was the Wind Tunnel Department of British Aerospace. The structure of the chapter is shown in figure 6.1.

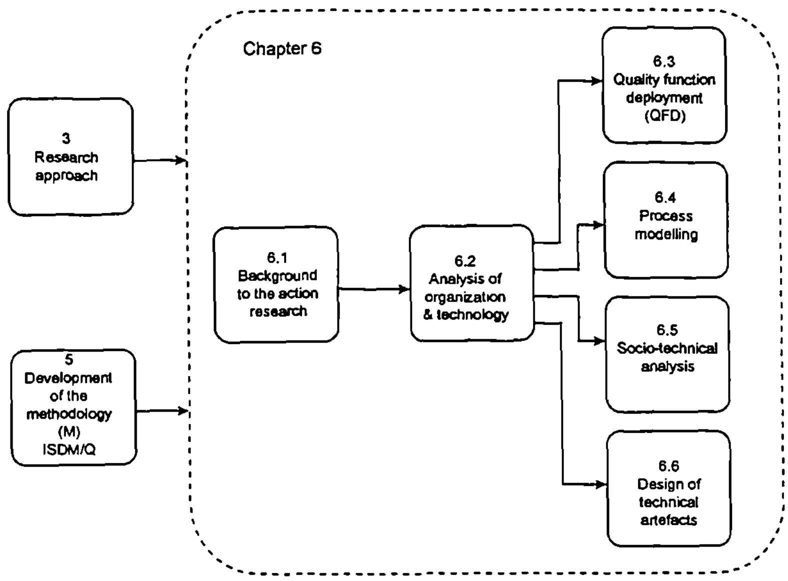


Figure 6.1: structure of chapter 6

6.1 Introduction to the action research

In November 1994 the author met with the Head of Technical Computing to discuss potential projects for the IS Quality Project. This meeting resulted in a project known as "R17" being identified, a project concerned with the development of software to support wind tunnel operation. A follow-up meeting was held with the R17 developer and R17 project leader in March 1995. At this stage, prototyping for R17 was already well under way and when the author joined the project the view of those involved with R17 was that the IS Quality initiative would proceed in parallel with R17, but that it would not be expected to change the terms of reference or the scope of the project. On one hand this was quite reasonable given that the ISDM/Q was at a formative stage. On the other hand, it is only by doing and achieving some outcome that the ISDM/Q could be developed and evaluated effectively. The net result has been that a middle ground has been pursued in which the ISDM/Q could be developed in a real-life situation, but at low risk to the R17 software development project. In appendix A the background to action research is described, including:

- a description of the Wind Tunnel Department (WTD) facilities;
- details of wind tunnel operation;
- WTD customers;
- WTD strategy;
- computing facilities;
- the aims and scope of project R17.

Although the description of the WTD and project R17 in appendix A is fairly detailed it is necessarily so if the reader is to gain a feeling for the situation in which the ISDM/Q has been applied and an understanding of the technical details of wind tunnel operation.

6.1.1 Entering the problem situation

The author decided not to take the R17 software development as the starting point for the research project. A simple strategy would have been to place the tunnel operation software at the centre of the perceived world and to identify stakeholders from that perspective. Obvious stakeholder groups would be tunnel operators and project supervisors since these are the people who are primary users of the wind tunnel software. Undoubtedly, these are the main users of the software in terms of their closeness to the computer system and the work that it supports, helping them to carry out their day to day duties. However, the aim of the research is to locate the R17 project in a larger context and to use the metaphor of customers and quality to understand the wider implications of the information system development project. The organizational analysis therefore began at the level of the Wind Tunnel Department (WTD). It is fair to comment that the software development team and even some WTD personnel found it hard to see why the focus was this wide. However, it is intended to demonstrate that coming "outside-in" from a wide organizational context does not necessarily give the same results as going "inside-out" from a narrow context.

6.2 Analysis of organization

6.2.1 Situational analysis

6.2.1.1 Rich picture

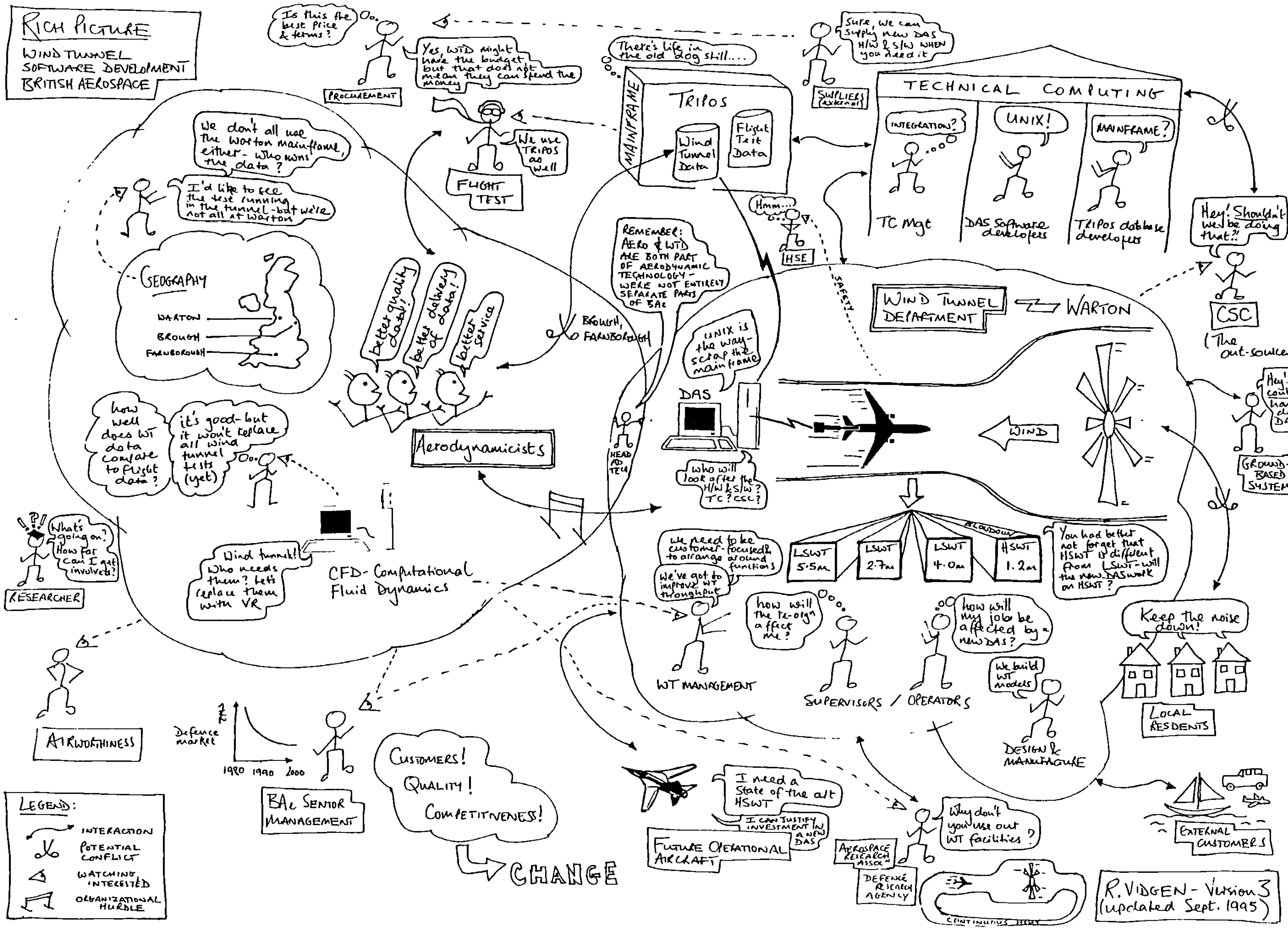
The rich picture provides on a single sheet a graphical and heterogeneous representation of complex and messy situations. It supplements and often replaces the thick textual descriptions that are more typical of feasibility reports and preliminary analyses. Figure 6.2 is a rich picture developed by the researcher following a number of interviews of BAe personnel. The rich picture evolved and addressed more specifically the issues of one particular computer system development project as the researcher gained a deeper understanding of the situation in which the Wind Tunnel Department was working. Figure 6.2 is the third version of the rich picture produced in the period March through September 1995. This rich picture includes human and non-human actors, reflecting a view consistent with that described in actor-network theory (Callon et al. 1986). According to this approach a computer system can be included as an actor that has concerns, such as "who is going to maintain the operating system?".

6.2.1.2 Stakeholder analysis (SAST)

Mitroff & Linstone (1993, p.141) show a stakeholder map for a drug company, but do not describe the process through which stakeholders were identified - one of the benefits of developing a rich picture is that it provides a basis for thinking about stakeholders. Mitroff & Linstone's (1993) social view of stakeholders and organizations has been extended to include non-human stakeholders, requiring a revised definition of stakeholder (Vidgen & McMaster 1996):

> Stakeholders are any human or non-human organization unit that can affect as well as be affected by a human or non-human organization unit's policy or policies. (p. 255)

In the above definition *organization unit* is used to cater for individuals through institutions and, for example, a computer chip through the interNet. The word organization is used in the cybernetic tradition, where the organization of a system defines the identity of the system (Beer 1981; Maturana & Varela 1980).



RICH PICTURE
WIND TUNNEL SOFTWARE DEVELOPMENT
BRITISH AEROSPACE
Is this the best price & terms?
PROCUREMENT
Yes, WTD might have the budget but that does not mean they can spend the money
We use TRIPOS as well
FLIGHT TEST
There's life in the old dog still....
MAINFRAME
TRIPOS
Wind Tunnel Data
Flight Test Data
Sure, we can supply new DAS H/W & S/W when you need it
SUPPLIERS (external)
TECHNICAL COMPUTING
INTEGRATION?
UNIX!
MAINFRAME?
TC Mgt
DAS Software developers
TRIPOS database developers
Hey! Shouldn't we be doing that?!
CSC
(The out-sourcer)
We don't all use the Warton mainframe, either - who owns the data?
I'd like to see the test running in the tunnel - but we're not all at Warton
GEOGRAPHY
WARTON
BROUGH
FARNBOROUGH
better quality data!
better delivery of data!
better service
Aerodynamicists
BROUGH, FARNBOROUGH
Hmm....
HSE
SAFETY
REMEMBER: AERO & WTD ARE BOTH PART OF AERODYNAMIC TECHNOLOGY - WE'RE NOT ENTIRELY SEPARATE PARTS OF BAe
WIND TUNNEL DEPARTMENT
WARTON
UNIX is the way - scrap the mainframe
DAS
Who will look after the H/W & S/W? TC? CSC?
HEAD AD TECH
WIND
Hey! We could have done DAS
GROUND-BASED SYSTEMS
how well does WT data compare to flight data?
it's good - but it won't replace all wind tunnel tests (yet)
What's going on? How far can I get involved?
RESEARCHER
Wind tunnel! Who needs them? Let's replace them with VR
CFD - Computational Fluid Dynamics
We need to be customer-focused & to arrange around functions
We've got to improve WT throughput
LSWT 5.5m
LSWT 2.7m
LSWT 4.0m
HSWT 1.2m
BLOWDOWN
You had better not forget that HSWT is different from LSWT - will the new DAS work on HSWT?
how will the re-org affect me?
how will my job be affected by a new DAS?
WT MANAGEMENT
SUPERVISORS / OPERATORS
We build WT models
DESIGN & MANUFACTURE
Keep the noise down!
LOCAL RESIDENTS
AIRWORTHINESS
Defence market
£
1980 1990 2000
BAe SENIOR MANAGEMENT
CUSTOMERS! QUALITY! COMPETITIVENESS!
CHANGE
I need a state of the art HSWT
I CAN JUSTIFY INVESTMENT IN A NEW DAS
FUTURE OPERATIONAL AIRCRAFT
Why don't you use our WT facilities?
AEROSPACE RESEARCH ASSOC.
DEFENCE RESEARCH AGENCY
CONTINUOUS TESTS
EXTERNAL CUSTOMERS
R. VIDGEN - Version 3 (updated Sept. 1995)
LEGEND:
INTERACTION
POTENTIAL CONFLICT
WATCHING INTERESTED
ORGANIZATIONAL HURDLE

A stakeholder map for the WTD is shown in figure 6.3, in which non-human stakeholders are shown as shaded boxes. In different situations there might be further and more elemental non-human stakeholders. For example, a real-time flight control system must be able to cope with the low temperatures associated with high altitudes; in such a case the weather can be thought of as a stakeholder. As non-human stakeholders cannot speak for themselves representatives need to be appointed. In one sense this is no different from the task of identifying representatives of human stakeholder groups, since assumptions need to be made about the stakeholder group and therefore the analyst is likely to be faced with similar difficulties for human and non-human stakeholders: is the representative faithful to the interests of the stakeholder group? It is unlikely that it will be possible for each and every member of a human stakeholder group to be involved in an IS development, hence the need to appoint a 'sovereign' to represent the interests of the subjects. Similarly there is a need to appoint a representative to speak on behalf of the non-human stakeholders.

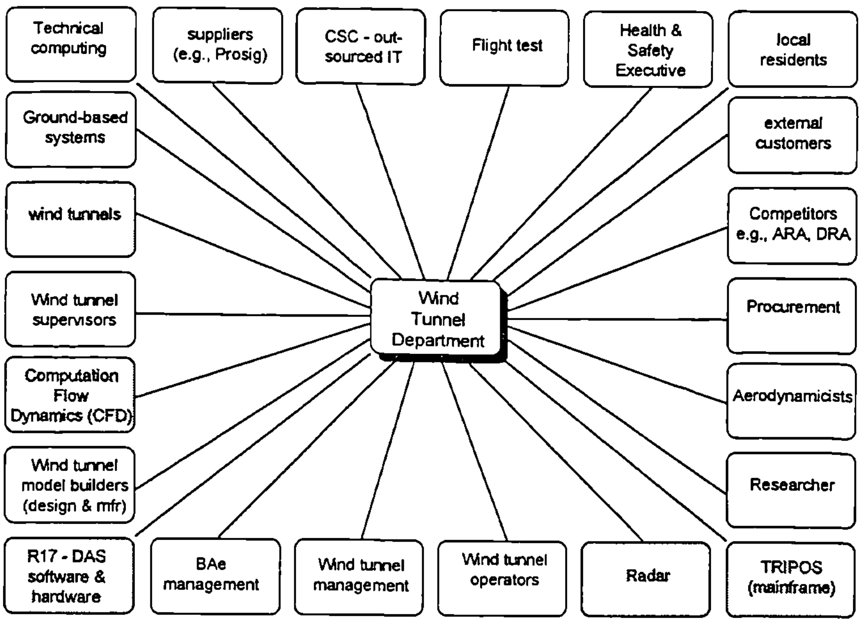


Figure 6.3: a stakeholder map for the Wind Tunnel Department in the context of R17

Issue-based assumptions (i.e., the focus was on the impact of R17 in particular rather than the WTD in general) were made, representing the development team's assumptions about stakeholders. The key assumptions about the human and non-human stakeholders identified in figure 6.3 are listed in tables 6.1 and 6.2

respectively. These are the assumptions made by the author and the WTD representative about the stakeholders who might be affected by project R17. With respect to R17 the feeling of the WTD was that there was no need to discuss at length the identity of customers - the WTD believe that aerodynamicists are the customer and debate about further potential customers was not considered to be a meaningful exercise. One could argue that this is a restrictive view of the project, or that political issues and the exercise of power make it difficult to talk about the impact on other stakeholders. In the author's opinion, a reasonable interpretation to make is that the R17 project team see the situation as unitary rather than pluralistic and that conducting a full SAST process would not be perceived to be useful.

Stakeholder	**assumption re R17**
Local residents	will not complain about noise levels
External customers	will have a higher level of customer satisfaction with the WTD
Competitors	will not upgrade their facilities in response
Procurement	will be able to approve purchases to meet project timetable
Aerodynamcists	will have a higher level of customer satisfaction with the WTD
Researcher	will not impede the implementation of R17
Tunnel operators	will accept new tunnel operation interface and working methods
Tunnel management	will support R17 project
BAe management	will not impose budget cuts that would result in R17 being halted
Modellers	not affected significantly by R17
Tunnel supervisors	will support new working methods
Ground-based systems	will not lobby to build R17 themselves
Technical computing	can construct R17 to timescale, budget, and functionality
Suppliers	can supply resources to meet timescale
IT out-sourcer	will not interfere
Flight test	not affected significantly by R17
Health and Safety Executive	will accept the new tunnel operation as being at least as safe (safer?) as current operation

Table 6.1: assumptions about human stakeholders with respect to R17

Although the stakeholder analysis did not result in any obvious changes to the project, it did provide an opportunity for cross-checking of assumptions about the stakeholders who might be affected by R17. In situations perceived as containing greater degrees of pluralism then SAST should provide more tangible benefits.

Also, one does not know how the situation will play itself out; it is possible (indeed likely) that there are further relevant stakeholders who will rear their heads as the project proceeds and, in fact, one new stakeholder did arise as the project progressed. The WTD was subject to a quality audit as part of gaining third part accreditation under ISO9000 and the procedures, audit trails, and authorizations required for conducting wind-tunnel tests were scrutinized. Certainly, failure to take account of the quality auditors' requirements of R17 could have had severe and far-reaching consequences.

Stakeholder	assumption re R17
TRIPOS (Mainframe computer)	can process data from new data acquisition system (DAS)
Radar	will not interfere with DAS through generation of large electro-magnetic fields
R17 software & hardware	can meet needs of tunnel and tunnel operators (user interface) and data acquisition
Computational Flow Dynamics	cannot replace the wind tunnels
Wind tunnels	can be controlled using R17

Table 6.2: assumptions about non-human stakeholders with respect to R17

Having identified the aerodynamicists as the traditional customer it we could now test our assumptions about what aerodynamicists want from the WTD and gather their quality requirements. This was done by conducting quality requirements workshops and is described in section 6.2.3. In parallel with situational analysis and quality requirements gathering systemic models were created to give a conceptual insight into WTD activity.

6.2.2 Systemic modelling & re-visioning

Soft Systems Methodology (SSM) was used to conceptualize and re-vision WTD activity. The approach adopted to the analysis was mode 2 analysis, in which the SSM practitioner uses the ideas of SSM to structure the analysis of a situation whilst not attempting to train those involved in the language and methods of SSM. It was neither appropriate nor possible for the author to train WTD personnel in the techniques of SSM. Consequently the process of carrying out an SSM analysis in the WTD was conducted on an informal basis, with the researcher holding interviews and discussions with WTD personnel. Furthermore, the language of SSM

SYSTEM DEFINITION OF:

S(1) Satisfy need for aerodynamic data

ROOT DEFINITION:

An Aerodynamic Technology owned system operated by Wind Tunnel Department in conjunction with aerodynamicists to acquire data concerning the aerodynamic characteristics of an object by carrying out a series of tests on a model of the object in a wind tunnel, subject to limitations of scaling effects, flow representativeness and model accuracy.

CUSTOMERS OF THE SYSTEM

Advantaged	*Diasadvantaged*	*Other stakeholders*
Aerodynamicists		Flight Test Projects

ACTORS

Wind tunnel project supervisors and tunnel operators
Aerodynamicists

TRANSFORMATION

need for data concerning aerodynamic characteristics of an object → T → that need met

WELTANSCHAUUNG

For reasons of cost and safety it is not always possible or appropriate to carry out aerodynamic tests on a target object. It is possible to understand the aerodynamic characteristics of an object by creating a model of the object and conducting test on the model in a wind tunnel.

OWNERSHIP

Aerodynamic Technology

ENVIRONMENTAL CONSTRAINTS

Limitations of scalability from model to object
Representativeness of tunnel
Accuracy of model

SUCCESS CRITERIA

Efficacy	*Efficiency*	*Effectiveness*
is the need for aerodynamic data satisfied?	how much effort is expended in acquiring aerodynamic data? how long does it take to produce the data?	how well does the simulated data correspond to flight test? is it cheaper and safer than testing on target objects?

Figure 6.4: SSM primary task model that might be an appropriate basis for debate concerning the activities of the Wind Tunnel Department

was avoided, particularly words and phrases such as 'Weltanschauung', 'transformation', 'systemic desirability', and 'stream of cultural analysis'. The author asked (continually!) the basic questions "*what* is to be done" (transformation) and "*why* should it be done" (Weltanschauung). Subsidiary questions included *how*, *who*, *when*, and *where*. This approach allowed the ideas from an SSM analysis to be presented in a language that was familiar to BAe personnel.

6.2.2.1 Conducting the soft systemic analysis

The author created models of purposeful activity that might be relevant to the WTD, such as the model shown in figure 6.4. This model is a primary task model, that is, it is a model that might be relevant when discussing what it is that a WTD does and why that activity might be meaningful. Associated with the SSM definition in figure 6.4 is an activity model (figure 6.5). This shows the minimum activities required to accomplish the Transformation given in figure 6.4.

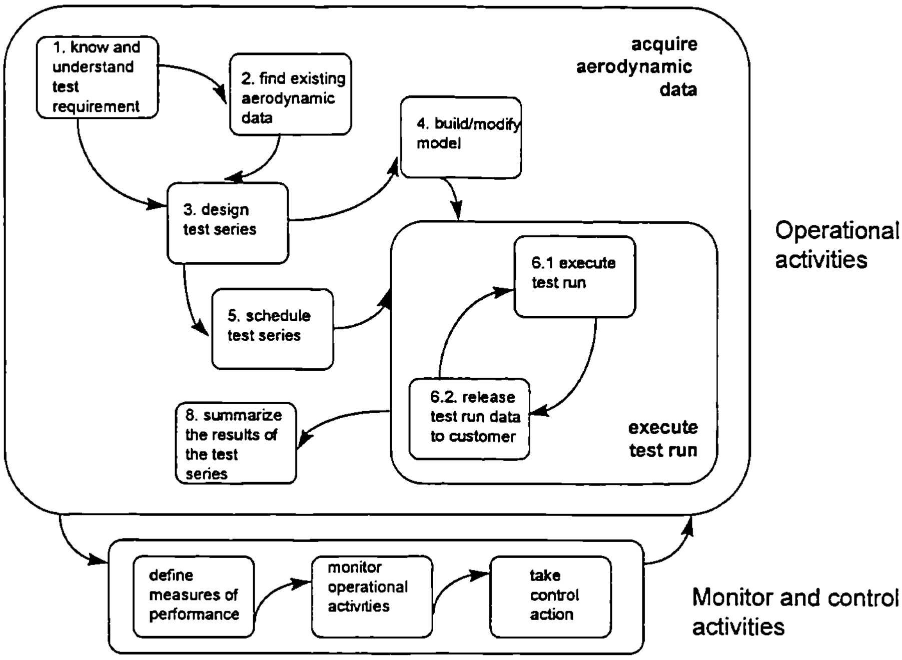
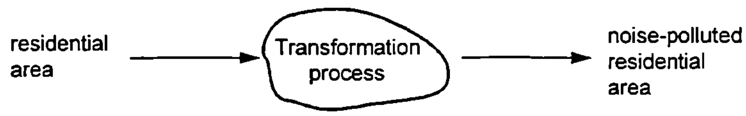


Figure 6.5: activity model derived from figure 6.4

The success of a transformation is evaluated using the 3Es (efficacy, efficiency, and effectiveness) described in chapter 5. The activity 'define measures of performance' in figure 6.5 is concerned with the 3Es and requires those making an intervention to confront the issue of success how we might ascertain the degree of success with which a transformation is achieved.

However, one should also consider different conceptualizations of purposeful activity in the WTD since these different models might give an insight into whether or not an intervention in the WTD will be successful. Consider an alternative T and W that might be relevant to another stakeholder group, the local residents (figure 6.6).

Transformation (what)



Weltanschauung (why)

I like to sit in the garden and read my newspaper in peace and quiet and to get an undistrubed night's sleep.

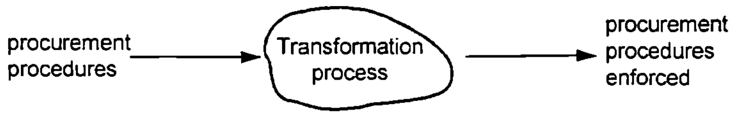
Figure 6.6: SSM primary task model that might be appropriate to local residents

Wind tunnels produce noise as well as aerodynamic data and this noise can be invasive for local residents. Should the WTD decide to operate the tunnels into the night-time, or during weekends, then they might find that local residents will lobby the local council for restrictions to be placed on the hours of wind tunnel operation (for example, no test runs after 6.00 p.m. and no week-end operation). Although one would not think of local residents as a customer, by formulating a root definition that is relevant to this stakeholder group it is possible to cast them as an SSM Customer (in this case victim). The general and on-going assumption might be that local residents will not campaign for shorter hours of operation.

The author put the local residents scenario to the head of the WTD, who pointed out that the presence of the wind tunnels means that the need for flight tests is reduced, and that therefore the noise level is reduced (flight tests are very noisy) and safety is increased since flight tests are carried out with a greater degree of confidence. This demonstrates the value of SAST and SSM as a basis for debate in which assumptions can be surfaced and discussed.

It is also possible to use SSM to create *issue-based* models of purposeful activity. In the case of the R17 project one might ask 'why' and 'what' questions, as was done with the WTD itself. In appendix A the motivation for R17 is given to be the achievement of improvements in data quality and data acquisition system (DAS) reliability in the high speed wind tunnel (HSWT). It might, therefore, be appropriate to formulate a systemic model for improving the quality of aerodynamic data. However, it is also noted in appendix A that a further benefit of R17 is to promote operator mobility through the utilization of common tunnel operation interfaces; in this case one might see R17 as a system to support a process of organizational change in which the WTD moves from a tunnel-based organizational structure to a facility-based structure (see figure A.2 in appendix A). As with the primary-task analysis of the WTD, there are many views that might be taken of the R17 project, as, for example, shown in figure 6.7, in which the R17 project is seen as an exercise in procurement management, a view that might be relevant to the Purchasing Department.

Transformation (what)



Weltanschauung (why)

Just because departments have got a budget does not mean that they can spend the money. It is vital to the organization that we get value for money and to do that we must have centralized and professional procurement services.

Figure 6.7: SSM issue-based model that might be appropriate to a procurement department

In the SSM orthodoxy (Checkland 1995) SSM models are not intended to describe what the WTD *is* or what the R17 project *is*. Neither should it be assumed that SSM models describe what the WTD or R17 *ought* to be - SSM models are devices that serve as a basis for coherent and informed discussion, for the surfacing of assumptions, and for the creation of a shared understanding (possibly a consensus, but at least an accommodation of interests). Such models should then *inform* a successful intervention in the real world problem situation.

6.2.2.2 Re-visioning

The transformation outlined in figure 6.4 has been constrained by a 'how', namely the use of wind tunnels (although *this constraint was excluded deliberately* from figure 6.5 which is a conceptual view of the collection of aerodynamic data). There are other ways of satisfying the need for aerodynamic data, such as the use of Computational Fluid Dynamics (CFD) in which forces and moments are simulated using computer-based models. The Transformation described in figure 6.4 is supported by a particular Weltanschauung, which contains an assumption that aerodynamic data needs to be generated in a physical wind tunnel. We can modify the Weltanschauung so that the systemic model can cater for different sources of aerodynamic data, including CFD and even flight test data.

The success factor E3, effectiveness, is concerned with the longer term aims of the system. To address this question one needs to ask why aerodynamic data is of value at all. To explore this question the author asked aerodynamicists directly in workshops and interviews why they need aerodynamic data. Once the initial reaction ("nobody's asked us that before, it's obvious......") was surmounted, we found that it was rather more difficult than it appeared at first sight to explain why aerodynamicists need wind tunnel data. To put the operations of the WTD in a wider organizational context models of purposeful activity that might be relevant to aerodynamicists, the principal customer of the WTD, were formed. The SSM definition in figure 6.8 was formulated, being "a system to solve aerodynamic problems". Once again, as with the WTD, this is not a description of what Aerodynamic Technology *is*; it is a relevant model that can be used for debate. From the systems model in figure 6.8 an activity model has been formulated (figure 6.9).

Activity 5 of figure 6.9 is concerned with the acquisition and management of aerodynamic data. An implication of this is that wind tunnels (physical simulations) are but one way of collecting aerodynamic data - one can collect data from third party wind tunnels, from CFD (virtual simulations), and from flight test (and no doubt from other sources too). In this formulation the role of a WTD might be to act as data managers, responsible for the quality of the data, where one measure of

SYSTEM DEFINITION OF:

S(1) Demonstrate aerodynamic characteristics

ROOT DEFINITION:

An Aerodynamic Technology owned and operated system to create (modify) object designs that have acceptable aerodynamic characteristics by building mathematical models of aerodynamic characteristics of an object and testing those models through simulation prior to flight test in order to meet the operational needs of Airframe Technology and other external customers, subject to airworthiness requirements.

CUSTOMERS OF THE SYSTEM

Advantaged	*Diasadvantaged*	*Other stakeholders*
Airframe Technology External customers		Flight Test Airworthiness

ACTORS

Aerodynamic Technology

TRANSFORMATION

object design → T → object design with acceptable aerodynamic characteristics

WELTANSCHAUUNG

New operational requirements arise that require new and modified aircraft (objects). Cost and safety concerns mean that any new design must be demonstrated to be aerodynamically sound before manufacturing takes place.

OWNERSHIP

Aerodynamic Technology

ENVIRONMENTAL CONSTRAINTS

Airworthiness
Computing power (price/performance)

SUCCESS CRITERIA

Efficacy	*Efficiency*	*Effectiveness*
Are acceptable aerodynamic solutions supplied? How close is the aerodynamic model to flight test?	How much resource is used?	Are operational requirements satisfied?

Figure 6.8: SSM primary task model that might be an appropriate basis for debate concerning the activities of aerodynamicists

success might be the level of re-use of aerodynamic data. SSM is helpful in thinking about *what* (Transformation) is to be done, *why* (Weltanschauung) it is meaningful to do, and *how* (activity model) it might be done. In turning attention to *who* is to do it, the Actors of the CATWOE mnemonic, we could envisage a situation in which the wind tunnel is operated directly by an aerodynamicist (with significant real-world implications for tunnel operators).

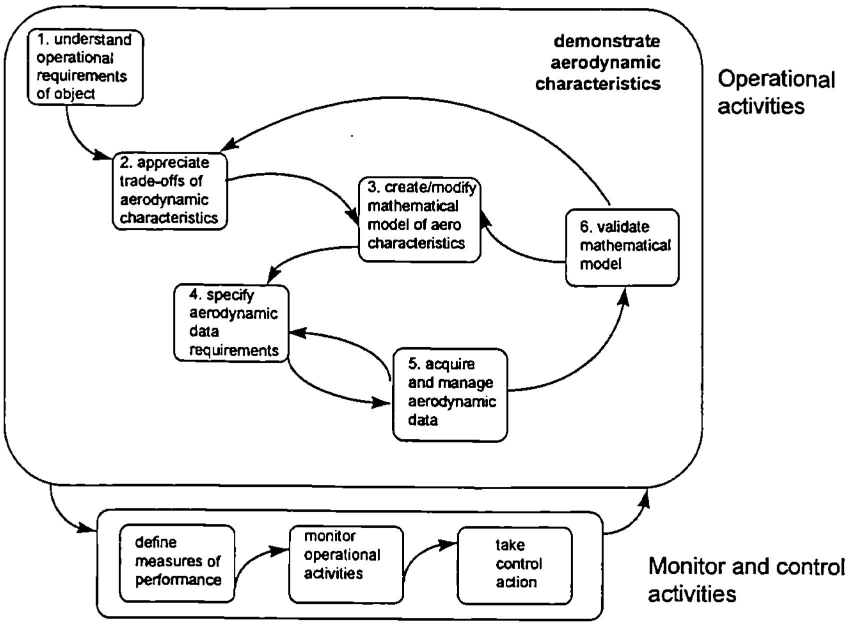


Figure 6.9: activity model for aerodynamicists

Furthermore, we envisaged a situation in which aerodynamicists could operate the wind tunnels remotely if information technology were used to give access to the tunnel operator's console together with video-conferencing to allow the (remote) aerodynamicist to both control and see a test run. This *who*-based analysis does not necessarily change *what* is to be done, but it does require us to think about the boundaries between customers and suppliers, which is a traditional outcome of Business Process Reengineering (see the description in Hammer & Champy (1993) in which Walmart Stores' inventory management function is transferred to a supplier, Procter & Gamble).

An intervention based upon the above re-visions would change the role of WTD significantly. This does not mean that the process should be redesigned on the basis of the re-visioning - the aim was to show that a focus on the operation of wind tunnels can result in a narrow and one-dimensional view of the world that can preclude radical change and even make incremental improvements difficult to achieve. In SSM terms, we might, for example, consider it systemically desirable to view WTD as data managers, but if such a view is not culturally feasible then even small changes in the organization that are based upon this view are unlikely to be successful.

6.2.3 Quality requirements gathering

Although SSM gives a powerful means of re-conceptualizing the problem situation and SAST allows stakeholders to be identified and the assumptions about stakeholders of those involved in the intervention to be surfaced, debated, and shared, neither approach provides a firm basis for the identification of specific qualities demanded by 'real-world' customers. From the stakeholder analysis and subsequent discussions aerodynamicists were identified as the principal customers of the WTD. In order to gather the "voice of the customer" a quality requirements workshop was held at each of the Aerodynamic Technology locations (Warton, Brough, Farnborough). Each site was asked to supply around six representatives for a workshop. The workshops were conducted by the author supported by the WTD R17 representative and followed the guidelines set out by Bossert (1991) for gathering quality requirements:

- establish a single issue for discussion
- collect quality requirements and functions using post-its
- use affinity grouping to gather requirements into categories that make sense to the customer.

The basic approach was the same for each workshop (table 6.3) and involved the workshop leader giving a brief introduction to the purpose and aims of the workshop followed by asking the question: "what are the qualities demanded by aerodynamicists of an excellent wind tunnel department?" No more guidance was given, other than to ask the attendees not to be constrained by existing operations, organization structure, and cost factors. Responses were recorded on post*It* notes and placed on a large conference table. The aerodynamicists were encouraged to record their requirements directly onto the post*It*s. In some instances the author or the WTD representative recorded requirements onto the post*It*s but, regardless of who wrote the post*It* text, the aim was to capture the customer's words using the customer's terminology and phrasing and to minimize unsubstantiated assumptions made by the author or the WTD representative about the meaning of the text (these data sources are known as *customer verbatims*).

Activity	responsibility	planned duration
introduction	WTD representative	10 minutes
purpose and objectives of the workshop	Workshop leader	10 minutes
review of the current situation	All	40 minutes
quality requirements gathering	All	75 minutes
quality requirements grouping	All	30 minutes
summary and wrap-up	Workshop leader	15 minutes
	total time	**3 hours**

Table 6.3: workshop planning

Once sufficient ideas had been captured, the aerodynamicists were asked to conduct affinity grouping, which involves participants in grouping post*It*s that appear (to them) to be related in some way. Once the groups had been formed then a post*It* was chosen to represent the group; if there was no suitable post*It* in the group then a new post*It* was created to act as a group header. This data was taken away and the results of the three workshops were used as the basis for the creation of a tree-structured list of *demanded qualities*.

At the end of each workshop questionnaires were distributed to elicit attendees' responses to the workshop (appendix B). The workshops varied considerably by site and the organization of the workshops changed as we learnt from experience. The individual workshops are now described in chronological order. Summaries of the feedback from workshop participants are given for each workshop.

6.2.3.1 Quality requirements workshops

Warton quality requirements workshop

The workshop was held 12 April 1995 and lasted from 2.00 p.m. until 5.00 p.m. The attendees included five aerodynamicists based at Warton, a representative of the WTD, two representatives from the Software Quality Assurance Directorate (the project sponsors), and the author.

In this workshop a rich picture prepared by the author was photo-enlarged to double A3 size and two copies were taped to the conference room table. The aim was to use the rich picture to gather perceptions of the current situation and to surface issues and concerns prior to talking about what might constitute the aerodynamicists vision of an excellent WTD. The aerodynamicists were divided into two groups, given coloured felt-tip pens and asked to annotate, amend, and emend the rich pictures. One group wrote copious notes on the diagram, but the majority of comments related to detail technical requirements and, it could be argued, did not add to the "richness" of understanding of the situation. The other group entered into the spirit of the rich picture rather more and made comments of a more general nature. All of the comments written on the rich pictures were recorded and retained as a verbatim source. The verbatims collected in the Warton workshop are contained in appendix B.

Participant feedback

- all of the participants would have liked a briefing document so that they would know what they were getting themselves into and to ensure that appropriate Aero representatives would be available;
- the workshop was felt to be a good way of getting ideas flowing; a process helped along by the rich picture;
- the workshop need to be followed up by further meetings. One participant suggested that the WTD/Aero interface group be re-introduced; this group has been revived and would be a suitable organizational forum for pursuing some of the issues raised in this research project.

Brough quality requirements workshop

The workshop was held 22 June 1995 and lasted from 2.00 p.m. until 5.30 p.m. The attendees included five aerodynamicists based at Brough, a representative of the WTD, and the author.

Given the feedback from the Warton participants, the Brough participants were sent details of the workshop in advance, including an agenda and two pages of details concerning the aims and objectives of the workshop and the techniques to be used (appendix B). They were also sent the rich picture in advance and asked to think about it prior to the workshop. The Brough aerodynamicists were noticeably reluctant to write on the rich picture and were not very keen to write down ideas on the post*It*s. This seems to reflect the culture and style of Brough rather than any lack of interest or wariness - the discussions were long and wide-ranging and particularly informative to the WTD representative. The focus tended to be on the technical aspects of wind tunnel testing and less on the organizational and service aspects. We did not get on to grouping the post*It*s, possibly due to the informal style of the workshop. The verbatims collected in the Brough workshop are contained in appendix B.

Participant feedback

- "matters surfaced rather than seeing a route to their resolution; but perhaps that is as much as was expected and achievable at this time." This comment highlights the need for participants to believe that the workshop will lead to action on the part of the WTD. Question 6 on the workshop questionnaire (appendix B) is concerned with this point - the respondent making the above comment was not confident that the WTD would take action based upon their customers' needs. This feeling was reflected in a number of the completed questionnaires;
- "well structured, worthwhile discussion which enabled several long-standing issues to be addressed" and, from another respondent, "a much needed airing of the topic". These comments reflected the value that can be gained from taking the trouble to talk to and listen to customers. However, one of the correspondents noted that a similar exercise had been carried out three year's ago and that nothing appeared to have happened since.

Farnborough quality requirements workshop

The workshop was held 6 July 1995 and lasted from 10.00 a.m. until 1.15 p.m. The attendees included five aerodynamicists based at Farnborough, a representative of the WTD, a representative of the Software Quality Assurance Directorate, and the author.

It was apparent from on arrival at Farnborough that this was a very different part of the organization as compared with Warton and Brough. The Farnborough site has new, modern, U.S.-style offices with landscaped surroundings, sculptures, and running water gardens. The reception area was modern, efficient and rather like an airline check-in desk. The aerodynamicists tended to adopt a more formal dress code: suits and ties (dark blues and greys rather than brown!). The Farnborough participants had been given the same details as the Brough attendees but, following the Brough and Warton workshops, we had decided that the rich picture would not be used at Farnborough. Consequently, the workshop was run with no props other than a flipchart and a pack of post*It*s. We began by talking about what Aerodynamic Technology do and the what product they supply and to whom. In raising issues about the current situation a multiple perspective model was adopted. The attendees were asked to think about issues using the following categories:

T	*technical* issues concerned with the wind tunnel facilities (e.g., sampling rates are too low)
O	*organizational* issues concerned with how Aerodynamic Technology and WTD work together (e.g., it takes too long to schedule a test run)
P	*personal* issues in any domain (e.g., WTD staff are off-hand)

This proved a very useful and simple structure for getting the attendees to think about the wider aspects of their dealings with the WTD and helped avoid getting caught up in technical details of wind tunnel operation. The feeling of the workshop organizers was that this workshop was particularly successful and subsequent dealings with Farnborough were very positive. This might reflect the fact that the Farnborough site is acclimatized to the notion of customer/supplier relationships and appreciated the opportunity of being treated as a customer themselves. The verbatims collected in the Farnborough workshop are contained in appendix B.

<u>Participant feedback</u>

- "an agreeably enjoyable workshop which worked better than I had thought. Not focusing on the narrow subject of the DAS allowed a number of topics to be explored" and "a very useful way to define broad requirements rather than getting bogged down in detail";
- "assuming that WTD do take action, the workshop was very worthwhile and entertaining" and "workshop excellent - but effectiveness is obviously dependent

upon follow-up activity - perhaps greater detail on certain areas, etc. As an effective medium as the 'first step' I would strongly agree".

6.2.3.2 Workshops - reflections

Having reflected upon the workshops, the author has the following comments:

- the participants for the workshops need to be chosen with care to ensure that they represent the wider interests of their department (in this case Aero);
- workshop participants should be briefed in advance to allow them to prepare and to remove any concerns about the unknown;
- running the workshop without props seems to work well - the blank sheet of paper approach. This requires a degree of skill in facilitation on the part of the workshop leader - these skills can be learnt the hard way by trial and error, but some formal training would certainly help;
- however much participants enjoy the workshop, they must leave the workshop feeling that the supplier will take some action based on their (the customers') stated needs;
- in conducting quality requirements workshops the supplier is building up the expectations of the customer and should only embark on these workshops if there is a genuine intention to make improvements that are achievable and that the customer will perceive to be relevant.

6.2.4 Technology foresight and future analysis

Further automation of the wind tunnel would seem to affect wind tunnel operators directly, since dedicated operators would no longer be needed . This did not seem to be a sensitive issue as tunnel operation as a sole occupation had already been superseded by a joint supervisor/operator role and it was an exception to have a dedicated operator. Given that the scope of the R17 project had not at this stage been changed and that the software was being developed iteratively through live prototypes the impact on tunnel operation was readily apparent. With respect to technology we could see ways of doing things differently.

A major issue for aerodynamicists was the ability to see wind tunnel test data being produced in real-time. With the current systems (figure A.3 in appendix B) processed data could only be accessed once the run was finished, following which the data was sent to the mainframe system TRIPOS for processing. This lead to delays in seeing the results of a test run and, more importantly, meant that an aerodynamicist sitting in the tunnel had to wait until the run was complete before a judgement could be made as to whether the data was usable. In experimental situations speculative changes are made and the aerodynamicist can tell if the data will be of any use from the first few data points. If the data is available in real-time then the run can be halted, further changes made, and the another run started. This approach results in significant improvements in tunnel throughput and enables the aerodynamicists to work more effectively.

Traditionally there has been reluctance on the part of WTD to release data that has not been checked; the attitude was "we know what they want and they can have it when we are happy with it". The quality workshops highlighted the fact that there is a genuine customer requirement for real-time data and that competitor facilities already supply this service. It also became apparent, aided by the soft systems analysis, that the old distinction between the data collection on UNIX work-stations and the data processing on a mainframe was an entirely artificial boundary constituted by the capabilities of 1980's computing. The advances in work-station processing power meant that data processing could be moved from the mainframe into a work-station environment, allowing test data to be processed in real-time. This would be expected to lead to a considerable improvement in customer satisfaction.

It was also clear from the workshops that the aerodynamicists were keen to cut down unproductive time spent travelling and sitting in the tunnel; we could envisage a situation in which data and video links would allow aerodynamicists to monitor test runs from their local offices. Video-conferencing for operators and aerodynamicists to communicate, real-time processed data in graphical form, fixed elevation cameras to display the model in the tunnel, and hand-held cameras for the tunnel operator to show specific details such as a lump of bluetak stuck on to the model. Going further, one could imagine that aerodynamicists could operate the wind tunnels remotely themselves since the wind tunnel control panel could be displayed remotely on a work station screen, with robots being used to mount and modify the models. Although this might be slightly fanciful in terms of today's technology it provides a liberating way of thinking about tunnel operation.

The aerodynamicists also wanted to be kept informed of the status and progress on a test series. We envisioned the use of a groupware product that the operators and supervisors would use to maintain a log of activity related to the life-cycle of a test series. If aerodynamicists were given access to the groupware then they could find out the status of their test series and the individual test runs without needing to send faxes, make telephone calls, and so on. This would also free WTD personnel from the need to take action to inform customers of progress as well as providing a good audit trail of actions taken in the wind tunnel, something required by quality management systems such as ISO9000.

By thinking of technology at this stage of the analysis it is possible to envision different and exciting futures. Of course, these different futures need investment and some will be neither technically nor culturally feasible. However, this type of analysis, taken with the qualities demanded by customers and the conceptual analysis of SSM adds a further dimension of richness to the intervention.

6.2.5 Summary

The analysis of organization module of the ISDM/Q is concerned with gaining a broad understanding of the problem situation from which stakeholders can be identified. Using SSM one can create both primary task and issue-based models that will inform debate and provide a basis for re-visioning current processes. To identify and understand real-world, detailed qualities demanded by customers quality requirements workshops were held. Finally, some imagination was used in thinking about what the future might be, informed by the SSM-informed re-visioning, customer requirements, and technology.

6.3 IS quality function deployment

IS quality function deployment (IS-QFD) is the "Q" element of ISDM/Q. The voice of the customer was identified through quality requirements workshops and these need to be transformed into a set of demanded qualities, which in turn are used as the basis for producing a quality plan. A set of QFD matrices are then designed that will support the deployment of demanded qualities through the IS development process.

6.3.1 Quality planning

6.3.1.1 Demanded qualities

Following the completion of the three workshops we now had approximately 100 customer verbatims. These verbatims represented a range of functional requirements and demanded qualities. The next task was to turn these verbatims into a consolidated set of qualities. This is an exercise in interpretation - it is not a deterministic process that leads inexorably to a statement of absolute and final customer requirements. Although we had the affinity groupings made by the aerodynamicists in the Warton and Farnborough workshops, it was still necessary to turn these into a coherent and consistent structure. However, we did not want to lose the audit trail from customer verbatim to demanded quality and to this end a *quality dictionary* was developed (appendix C). The quality dictionary contains a description of each quality together with comments and a section justifying the quality requirement in business terms. Each quality is cross-referenced back to one or more customer verbatims, reflecting a many to many relationship between customer verbatims and demanded qualities - the same verbatim may appear against a number of demanded qualities and one demanded quality may relate to a number of verbatims. The demanded qualities were structured into a three-level hierarchy. The outcome of the exercise is a list of demanded qualities and a quality dictionary (appendix C).

6.3.1.2 Formulating a quality plan

Once the qualities demanded by customers have been interpreted and structured then a quality plan can be produced, the purpose of which is to arrive at a demanded weight for each of the qualities demanded by the customer. The first task is to assign an importance to the qualities that reflects the customer's viewpoint. In this context we decided that the most appropriate way (particularly with respect to minimizing the use of aerodynamicists' time) to ask the customers to assign weights to the qualities would be to use a questionnaire (appendix D). This had the benefits of firstly providing an opportunity to verify (have we understood the qualities demanded) and validate (have we got the right qualities) and secondly to involve a wider audience by distributing the questionnaire to aerodynamicists who did not attend the workshops. In addition to the quality questionnaire, each site was given a copy of the quality dictionary to allow them to get further details concerning the qualities.

The questionnaire was also used to gather an assessment from the customer of the WTD's current performance with respect to the demanded qualities. If this survey were repeated at a later date it could be used to assess whether or not customer satisfaction has improved, although whether or not any improvement or deterioration of customer satisfaction could be attributed to the R17 project is an issue that would need to be considered carefully. In addition to finding out how the WTD is performing currently, the questionnaire was used to gather data on customer perceptions of competitor performance. One must be wary of treating third party wind tunnel sites as competitors insofar as a number of respondents pointed out that organizations such as the DRA (defence research agency) and the ARA (aerospace research association) offer a complementary service to the BAe WTD. However, whether complementary or competing this data is a useful benchmark of WTD performance. With hindsight, it would have been better to have made separate questionnaires for low-speed (LSWT) and high-speed (HSWT) wind tunnels - these are distinct facilities and by asking respondents to consider WTD as a whole it is likely that a degree of smoothing went on as aerodynamicists attempted to give an averaged response for all of the WTD's facilities.

The questionnaires were distributed in early September 1995 to the three sites. Eight completed questionnaires were received from Warton, seven from Farnborough, and three from Brough. Average values were calculated for importance, WTD performance and competitor performance (appendix D). The graph in figure 6.10 shows how customers rate the WTD against third party facilities, DRA and ARA. Although the differences are very small, the ARA, of which most respondents had knowledge of, rated more highly on most of the demanded qualities, the exceptions being staff conscientiousness and flexibility in scheduling of test series. These are perhaps not unexpected given that the

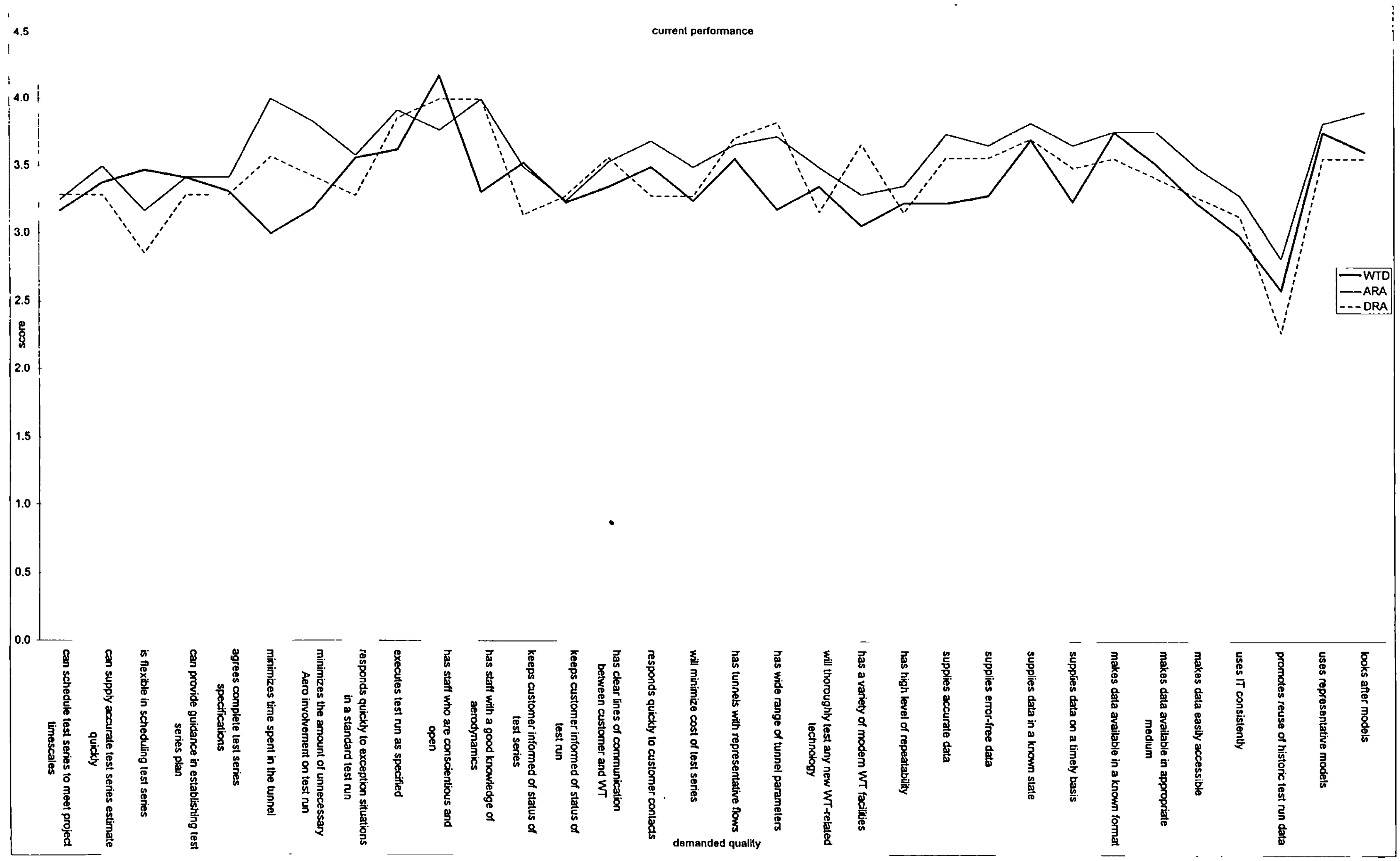


Figure 6.10: demanded qualities - current performance

Wind Tunnel Department

Quality plan - matrix A-1

(Version 3.1)

demanded quality (what)				quality plan													
						comp. anal.		plan			overall weight		service and product weights				
1st level	2nd level		3rd level	degree of importance (1-9)	BAe wind tunnels now (1-5)	ARA wind tunnels	DRA wind tunnels	quality plan	rate of improvement	sales point	absolute weight	demanded quality weight	absolute service weights	demanded service quality weight	absolute product weight	demanded product quality weight
Operations	Test series	1	can schedule test series to meet project timescales	7.6	3.2	3.3	3.3	4	1.3	1.25	12.0	4	12.0	6		
		2	can supply accurate test series estimate quickly	5.2	3.4	3.5	3.3	4	1.2	1.25	7.7	2	7.7	4		
		3	is flexible in scheduling test series	5.9	3.5	3.2	2.9	4	1.2	1.25	8.6	3	8.6	5		
		4	can provide guidance in establishing test series plan	5.1	3.4	3.4	3.3	4	1.2	1.00	5.9	2	5.9	3		
		5	agrees complete test series specifications	5.4	3.3	3.4	3.3	4	1.2	1.00	6.5	2	6.5	3		
		6	minimizes time spent in the tunnel	5.4	3.0	4.0	3.6	3	1.0	1.00	5.4	2	5.4	3		
	Test run	7	minimizes the amount of unnecessary Aero involvement on test run	5.0	3.2	3.8	3.4	4	1.3	1.00	6.3	2	6.3	3		
		8	responds quickly to exception situations in a standard test run	6.9	3.6	3.6	3.3	5	1.4	1.00	9.7	3	9.7	5		
		9	executes test run as specified	7.4	3.6	3.9	3.9	5	1.4	1.00	10.2	3	10.2	5		
Service	Staff	10	has staff who are conscientious and open	7.6	4.2	3.8	4.0	4	1.0	1.00	7.2	2	7.2	4		
		11	has staff with a good knowledge of aerodynamics	6.0	3.3	4.0	4.0	4	1.2	1.00	7.2	2	7.2	4		
	Communication	12	keeps customer informed of status of test series	7.3	3.5	3.5	3.1	4	1.1	1.25	10.4	3	10.4	5		
		13	keeps customer informed of status of test run	5.6	3.2	3.3	3.3	4	1.2	1.25	8.7	3	8.7	5		
		14	has clear lines of communication between customer and WT	7.2	3.4	3.5	3.6	4	1.2	1.00	8.5	3	8.5	5		
		15	responds quickly to customer contacts	7.3	3.5	3.7	3.3	4	1.1	1.00	8.3	3	8.3	4		
Cost	Cost	16	will minimize cost of test series	7.3	3.3	3.5	3.3	4	1.2	1.00	9.0	3	9.0	5		
Facilities	WT facilities	17	has tunnels with representative flows	7.8	3.6	3.7	3.7	4	1.1	1.50	13.2	4	13.2	7		
		18	has wide range of tunnel parameters	7.1	3.2	3.7	3.8	4	1.3	1.50	13.4	4	13.4	7		
	Technology	19	will thoroughly test any new WT-related technology	5.9	3.4	3.5	3.2	3	0.9	1.00	5.3	2	5.3	3		
		20	has a variety of modern WT facilities	5.9	3.1	3.3	3.7	3	1.0	1.00	5.8	2	5.8	3		
Data	Data quality	21	has high level of repeatability	8.1	3.2	3.4	3.2	5	1.5	1.25	15.6	5			15.6	12
		22	supplies accurate data	8.1	3.2	3.8	3.6	5	1.5	1.50	18.7	6			18.7	15
		23	supplies error-free data	8.4	3.3	3.7	3.6	5	1.5	1.00	12.7	4			12.7	10
		24	supplies data in a known state	8.4	3.7	3.8	3.7	5	1.3	1.25	14.2	5			14.2	11
	Delivery	25	supplies data on a timely basis	7.4	3.3	3.7	3.5	5	1.5	1.50	17.2	5			17.2	14
		26	makes data available in a known format	8.5	3.8	3.8	3.6	5	1.3	1.25	14.1	4			14.1	11
		27	makes data available in appropriate medium	7.1	3.5	3.8	3.4	4	1.1	1.00	8.1	3			8.1	6
		28	makes data easily accessible	7.3	3.2	3.5	3.3	4	1.2	1.50	13.6	4			13.6	11
		29	uses IT consistently	5.7	3.0	3.3	3.1	3	1.0	1.00	5.7	2			5.7	5
	Use	30	promotes reuse of historic test run data	5.4	2.6	2.8	2.3	3	1.2	1.00	6.2	2			6.2	5
Models	Models	31	uses representative models	7.7	3.8	3.8	3.6	5	1.3	1.25	12.8	4	12.8	7		
		32	looks after models	6.6	3.6	3.9	3.6	4	1.1	1.00	7.3	2	7.3	4		

Figure 6.11: quality plan

aerodynamicist and wind tunnel staff work for the same organization and that the wind tunnels are a strategic facility, retained specifically to give BAe assured access to wind tunnel testing.

Applying the quality planning techniques to the WTD demanded qualities resulted in the quality plan in figure 6.11. It will be noted that the quality requirements have been separated into service quality and product quality. Although it took some time to arrive at this distinction, as the project progressed it became apparent that we were not comparing like with like by treating all the quality requirements in the same way. This problem manifested itself particularly when we attempted to deploy the qualities into WTD operations. Thus, two sets of deployment are needed: one set for the product, which is aerodynamic data, and another set for customer service operations.

6.3.2 Deployment

QFD has a background in manufacturing, particularly in the automotive and aerospace industries. Despite this seeming good fit with BAe's operations, QFD in its raw form is suitable neither for service quality deployment nor for situations in which the product is not physical (data). In the context of the WTD it was necessary to carry out some quality deployment design that would account for data and service. By analogy part deployment has been equated with the parts of the product, these being things such as 'Customer', 'Test Run', and 'Test Series', which are more precisely known as *object types*. These product parts (object types) can then be deployed into the processes that 'manufacture' data. Service quality will be deployed directly into processes, since the product of a service is an intangible delivered via a service process. Finally, a technology deployment is used to allow us to consider the impact of IT at various levels. The connections between the different analyses are shown in figure 6.12.

The connections between the different matrices identified in the IS quality deployment planning matrix (figure 6.12) are represented in more detail in figure 6.13, showing that the voice of the customer is deployed through products and processes to technologies. The individual matrices are described in table 6.4.

QFD Design X = interaction analysis	Customer demanded qualities - service	Customer demanded qualities - product	User demanded qualities	Quality characteristics - service	Quality characteristics - product	Quality characteristics - sociotechnical	Operations	Parts - product	Technologies	Quality characteristics - technical artefacts
Customer demanded qualities - service	X			A1s					T2	
Customer demanded qualities - product		X			A1p				T1	
User demanded qualities			X			S1				
Quality characteristics - service				X			O1			
Quality characteristics - product					X		O2	P1		
Quality characteristics - sociotechnical						X				D4
Operations							X	O3		D3
Parts - product								X		D2
Technologies									X	D1
Quality characteristics - technical artefacts										X

X interaction analysis

Figure 6.12: planning for IS quality deployment

6.3.3 A1 matrices

The quality plan consists of qualities demanded by customers. These are soft and cannot be managed directly. The first step in quality deployment is to identify measurable characteristics of the product or service that the supplier considers, subject to a satisfactory quantity of the quality characteristic being achieved, will meet the qualities demanded by customers and therefore improve the level of customer satisfaction. The primary matrix is known as A1 and was used to map demanded qualities into quality characteristics.

To create the product and service characteristics a short workshop was held with wind tunnel personnel. This resulted in a number of characteristics that the WTD thought were important in satisfying customer demands. This workshop was held early on in the project (June 1995) before the quality workshops had been completed. Although we gathered some useful data, this is an area where considerable effort is needed on the supplier side to develop a dictionary of quality characteristics. However, although relatively sketchy, we developed a quality characteristics dictionary (appendix E) to demonstrate how measurable attributes of products and services might be developed. Using the qualities and the characteristics we created A1 matrices for the product (figure 6.14) and service (figure 6.15) supplied by the WTD.

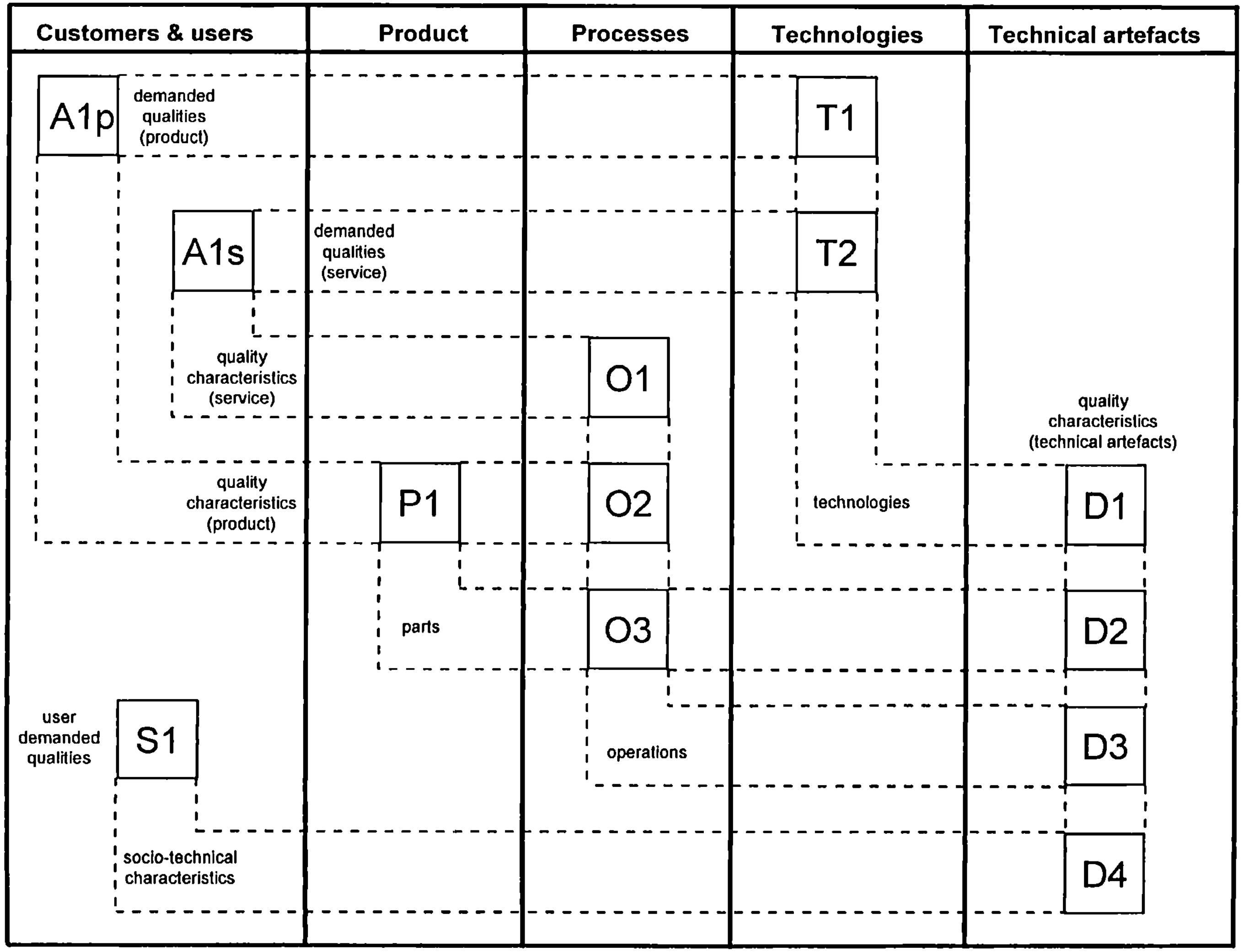


Figure 6.13: IS quality deployment design

matrix	from	to	purpose of matrix
A1p	demanded qualities (product)	quality characteristics (product)	to deploy soft qualities into hard characteristics of a product. which characteristics are most important with respect to the customer's view of product quality?
A1s	demanded qualities (service)	quality characteristics (service)	to deploy soft qualities into hard characteristics of a service. which characteristics are most important with respect to the customer's view of service quality?
P1	quality characteristics (product)	object types	to deploy quality characteristics of the product into object types - the parts of the product. which object types are most important with respect to the supplier's view of product quality?
S1	user demanded qualities	socio-technical characteristics	what are the requirements of users affected by the IS development?
O1	quality characteristics (service)	processes	to deploy quality characteristics of the service into processes performed by the WTD. which processes are most important with respect to the supplier's view of service quality?
O2	quality characteristics (product)	processes	to deploy quality characteristics of the product into processes performed by the WTD. which processes are most important with respect to the suppliers view of product quality?
O3	object types	processes	to deploy object types (parts of the product) into processes. how do processes and products interact?
T1	demanded qualities (product)	technologies	this is a tenuous link between soft qualities and hard technologies. It is useful as it provides a check that the voice of the customer has not been lost through the deployment process. how might technology be used to meet the qualities demanded by the customer of the product?
T2	demanded qualities (service)	technologies	how might technology be used to meet the qualities demanded by the customer of the service?
D1	technologies	technical artefacts	what technologies will be adopted in technical artefacts?
D2	object types	technical artefacts	how might technology be used to meet requirements for object types?
D3	processes	technical artefacts	how might technology be used to meet requirements for processes?
D4	socio-technical	technical artefacts	what are the features of the technical artefacts that will contribute to user satisfaction?

Table 6.4: IS quality deployments

Matrix A1p

Version 1.1

Demanded Qualities (product) and Quality Characteristics

+ = strong correlation (weight 9)
o = some correlation (weight 3)
^ = possible correlation (weight 1)

					quality characteristics																			
					data management												data usability							
					structure			security	definition			independence			duplication		accuracy		availability			traceability	traceability	
				demanded weight	redundancy	integrity	completeness	security	data definition completeness	data definition correspondence	data definition accessibility	hardware independence	application software independence	systems software independence	data duplication	processing duplication	absolute accuracy	comparison to flight test	timeliness	retention policy	range of media	traceability	same tunnel, same model, different time	same model, different tunnel
demanded qualities					39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
1st level	2nd level		3rd level																					
Data	Data quality	21	has high level of repeatability	12																			+	+
		22	supplies accurate data	15												^	+	o					o	o
		23	supplies error-free data	10	o	o	o			o					o	o								
		24	supplies data in a known state	11	^	o	+		o	+	+				o	+						+		
	Delivery	25	supplies data on a timely basis	14												^			+					
		26	makes data available in a known format	11					+	+	o											o		
		27	makes data available in appropriate medium	6								+	o	+							+			
		28	makes data easily accessible	11							o								o	+				
		29	uses IT consistently	5							o	+	o	+	o	o					o			
	Use	30	promotes reuse of historic test run data	5	^	o	o					o	+	o	o	o						o	o	o
				100																				

technical importance		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	
technical importance	absolute	47	79	147	0	135	233	181	113	77	113	93	189	133	44	155	97	71	150	170	170	2397
	relative (percentage)	2	3	6	0	6	10	8	5	3	5	4	8	6	2	6	4	3	6	7	7	100

Figure 6.14: matrix A1 - product

Matrix A1s

Version 1.1

Demanded Qualities (service) and Quality Characteristics

+ = strong correlation (weight 9)
o = some correlation (weight 3)
^ = possible correlation (weight 1)

1st level	2nd level		3rd level	demanded weight	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
			quality characteristics (service)																							
					Test management									WT management						Models		Facs		Tunnels		
					Estimating & Scheduling			Test plan		Test run execution				Staff			Communications		Use of computing	Models		Facilities		Tunnels		
					reliability of test series estimation	speed of production of test series estimate	lead time for scheduling of test series	rate of changes to specification	suitability of tunnel for test run	utilization of Aero staff time	rate of operator errors during test run	rate of model configuration errors	correct processing of data	level of WT operation experience	level of aerodynamic knowledge	satisfaction of Aero in dealing with WT staff	speed of response to customer contacts	level of awareness of Aero of WT staff responsibilities	level of manual intervention	model correspondence to drawing	completeness of model inventory	range of WT facilities	level of WT throughput	tunnel tolerances	tunnel parameters	tunnel flow uniformity
demanded qualities																										
Operations	Test series	1	can schedule test series to meet project timescales	6	O	O	+								O											
		2	can supply accurate test series estimate quickly	4	+	+																				
		3	is flexible in scheduling test series	5	^	O	+														O					
		4	can provide guidance in establishing test series plan	3										O	+											
		5	agrees complete test series specifications	3				+		O				O	^											
		6	minimizes time spent in the tunnel	3				O	O	+	O	O			^					O			+			
	Test run	7	minimizes the amount of unnecessary Aero involvement on test run	3				O	+	+	O									O			O			
		8	responds quickly to exception situations in a standard test run	5						O					O		O									
		9	executes test run as specified	5						O	+		+						O	^			+			
Service	Staff	10	has staff who are conscientious and open	4												+										
		11	has staff with a good knowledge of aerodynamics	4									^		+								+			
	Communication	12	keeps customer informed of status of test series	5												O	^									
		13	keeps customer informed of status of test run	5												O	^									
		14	has clear lines of communication between customer and WT	5												O		+								
		15	responds quickly to customer contacts	4												+	+									
Cost	Cost	16	will minimize cost of test series	5																						
Facilities	WT facilities	17	has tunnels with representative flows	7					O	^														+		+
		18	has wide range of tunnel parameters	7					+																+	
	WT Technology	19	will thoroughly test any new WT-related technology	3					^	O	^															
		20	has a variety of modern WT facilities	3					O		O								+			+	O			
Models	Models	31	uses representative models	7																+						
		32	looks after models	4								O								O	+		O			
				100																						
technical importance			absolute		60	69	98	49	135	113	79	20	52	20	103	118	65	41	44	96	48	27	139	63	64	63
			relative (percentage)		4	4	6	3	9	7	5	1	3	1	7	8	4	3	3	6	3	2	9	4	4	4

Figure 6.15: matrix A1 - service operations

6.3.4 Process performance indicators

Performance indicators should be developed for the process model that relate to the 3Es - efficacy, efficiency, and effectiveness - that were introduced in systemic modelling. Often the efficiency of the process will be measured in fairly crude terms, such as cycle time and cost. Effectiveness is more difficult to assess since by definition it is about longer term aims and therefore must address the issue of why the activity is done at all. In the context of the WTD this would mean looking at the role of the WTD in the context of Aerodynamic Technology and possibly on a wider basis, in the context of the design process. The 3Es are summarized in table 6.5, together with an orthogonal category for benchmarking.

Criterion	Indicator	Typical real-world assessment
Efficacy	does the process work?	• product conformance to specification
Efficiency	does the process use minimum resource (capability)	• time • cost
Effectiveness	does the process meet longer term goals?	• value added to the business by the process • customer-centred performance measures
Benchmarking	not applicable	• how well do others do the process?

Table 6.5: process performance indicators

These process indicators should be expected to overlap with the quality characteristics identified in response to demanded qualities. If they do not overlap then one must question whether the right processes are being performed at all. The process model should result in a coherent set of performance indicators that allow the supplier to control and improve the process in the context of what is demanded by customers.

6.3.5 Summary

IS quality deployment is used to deploy qualities demanded by customers of products and services into appropriate organizational processes, and from organizational processes to appropriate technical artefacts (software). In theory it should be possible to bridge the organization - information system - technical artefact divides using QFD and to provide measures (and hence a basis for improvement) while doing so.

6.4 Process modelling

This module consists of two activities: business process modelling and business object modelling.

6.4.1 Business process modelling

Drawing upon the systemic activity model developed in the analysis of organization module (figure 6.4) an event schema (figure 6.16) has been developed for the operations processes. The event schema can be decomposed hierarchically to give increasingly fine definitions of process. In figure 6.17 the operation 'execute WT test run' from figure 6.16 has been decomposed into a level 2 event schema, and in figure 6.18 the operation 'release WT test run data' is decomposed. The event schema for releasing test run data has introduced the categories "provisional", "checked" and "approved". The need for these categories was identified in the quality dictionary and in the characteristics dictionary. In the process model we can define precisely how a set of test run data is checked, by whom, and when. This is the type of defined process that is essential to quality assurance certification schemes such as ISO9000. Thus we can see that the definition of process models serves two purposes; firstly it points backwards to business requirements for defined processes, and secondly it points forwards to the development of computer systems.

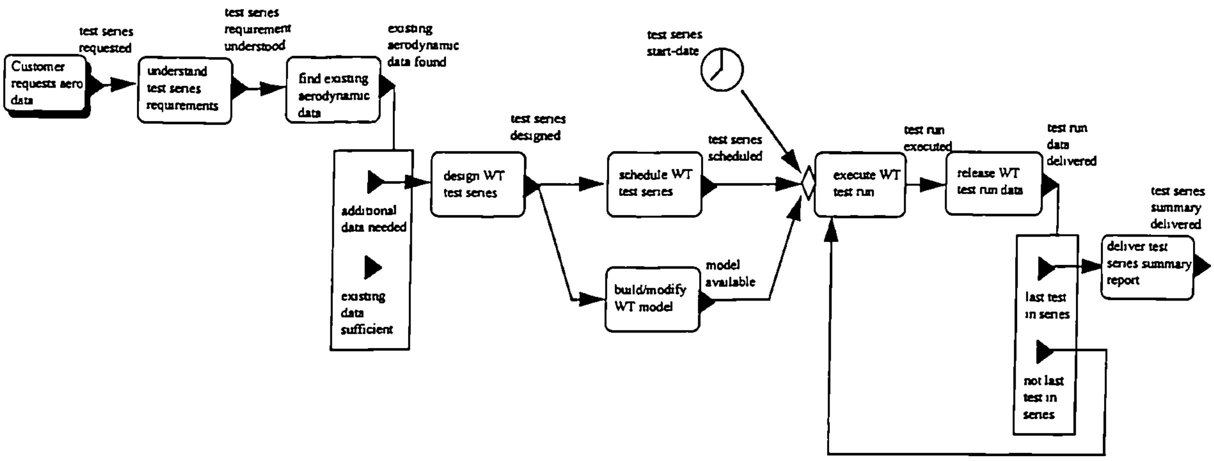


Figure 6.16: level 1 event schema for Operational processes in WTD

The operations in an event schema are decomposed until they are at a sufficient level of detail to be described in half a page of text, or by a simple flow chart, decision table, or similar technique. These primitive operations should form the procedures

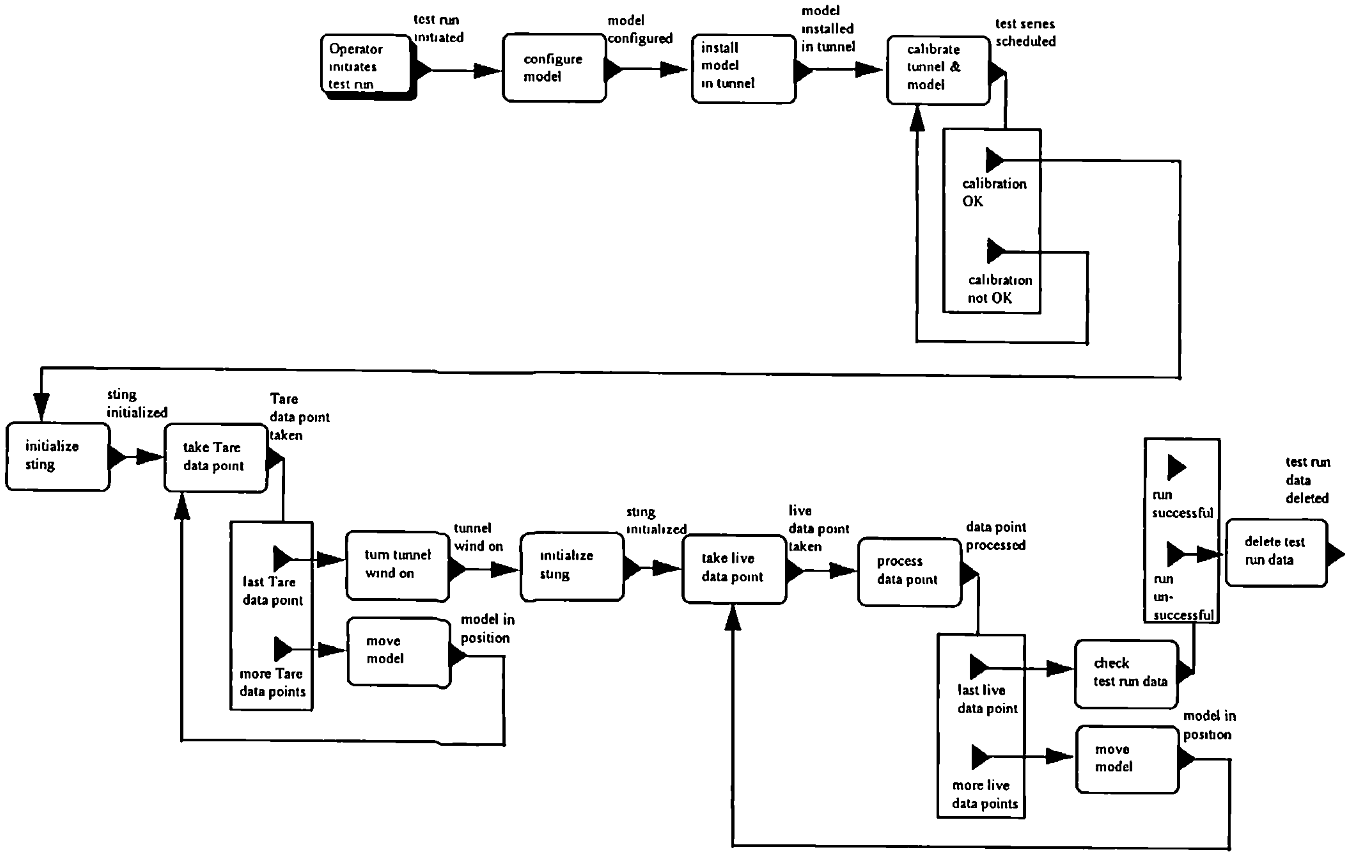


Figure 6.17: level 2 event-schema for executing a wind tunnel test series

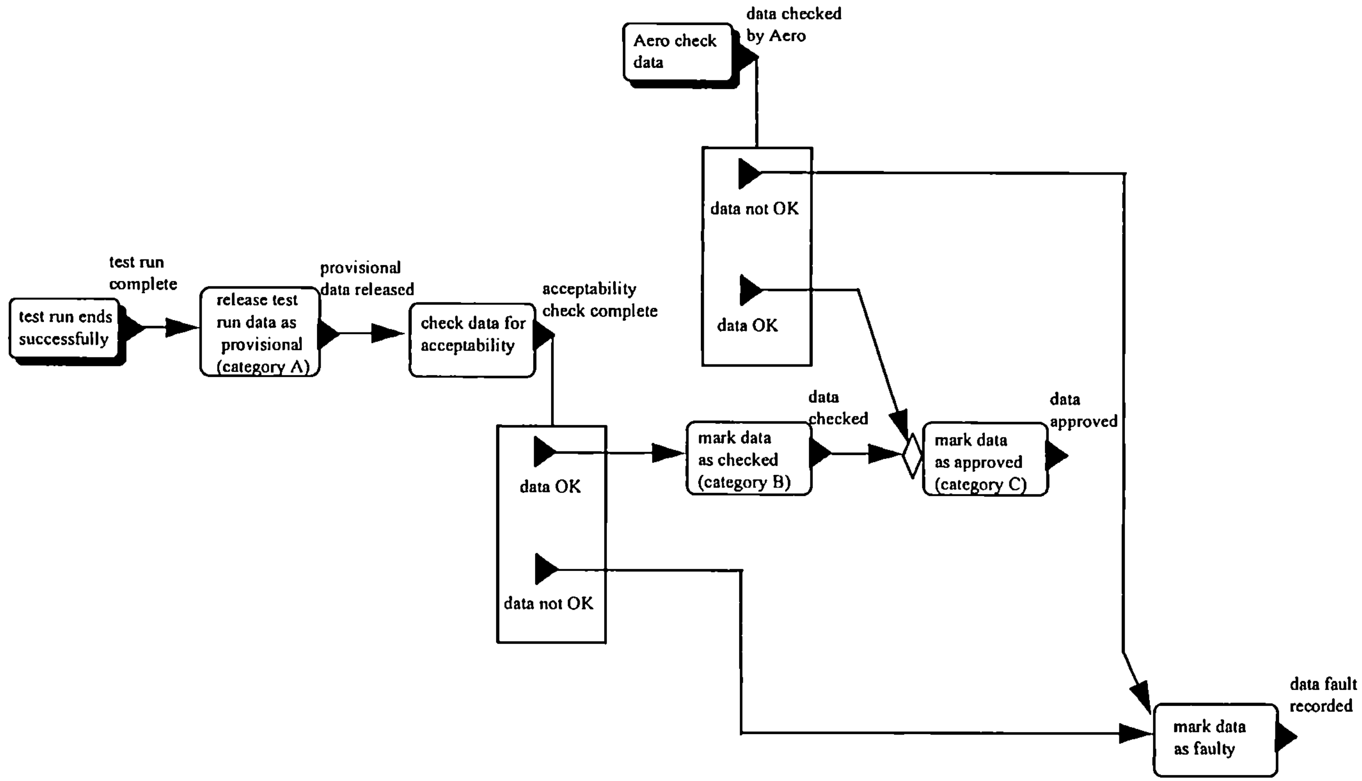


Figure 6.18: level 2 event-schema for releasing test data

manual for the WTD regardless of whether or not the operations are subsequently automated. It is the primitive operations that act upon the data stored in the information system (see de Carteret & Vidgen (1995) for further description of event schemas and object models and their interaction). The object types that processes act upon are represented using an object model.

6.4.2 Object model

The object model represents the types of data that are of interest to a WTD. In the object model in figure 6.19, object types of interest include Employee, Customer, and WindTunnelTestSeries. Associations between object types are shown by lines. For example, figure 6.20 shows that a test run *may* be checked by one project supervisor and each project supervisor may check many test runs. The object model also shows specializations of object types with the addition of triangles to the line, allowing object types, such as Employee, to be specialized, in this case into Modeller, Operator, and/or Supervisor. This means that a supervisor inherits all of the attributes and behaviour of employees in general, while adding specialist capabilities, such as the ability to check a test run (according to the model in figure 6.19 operators cannot sign-off a test run as being checked).

Associations can be strengthened and composition structures formed. This is shown by the addition of a diamond, which shows, for example, that a test series is *made up of* zero or more test runs. A special type of association is shown for the object type Model. This is a recursive association which shows that a model is made up of other models, is made up of other models, and so on. In its general form this structure is known as a bill of materials and is common in manufacturing, being used to show how the components of a product fit together. (Strictly speaking, the construction of a physical model is a hierarchy, a 1 to many recursive association, since each physical component, such as a wing, may only be fitted to one model at any given point in time. The specification of the model is indeed a bill of materials, a many to many recursive association, since different component types may be fitted to different model types.) Attributes of the object types are shown in the second section of the box. For example, attributes of the WindTunnelTestRun object type include actualTimeStart, plannedTimeStart, and testRunVideoRecording (this last attribute is itself an object type).

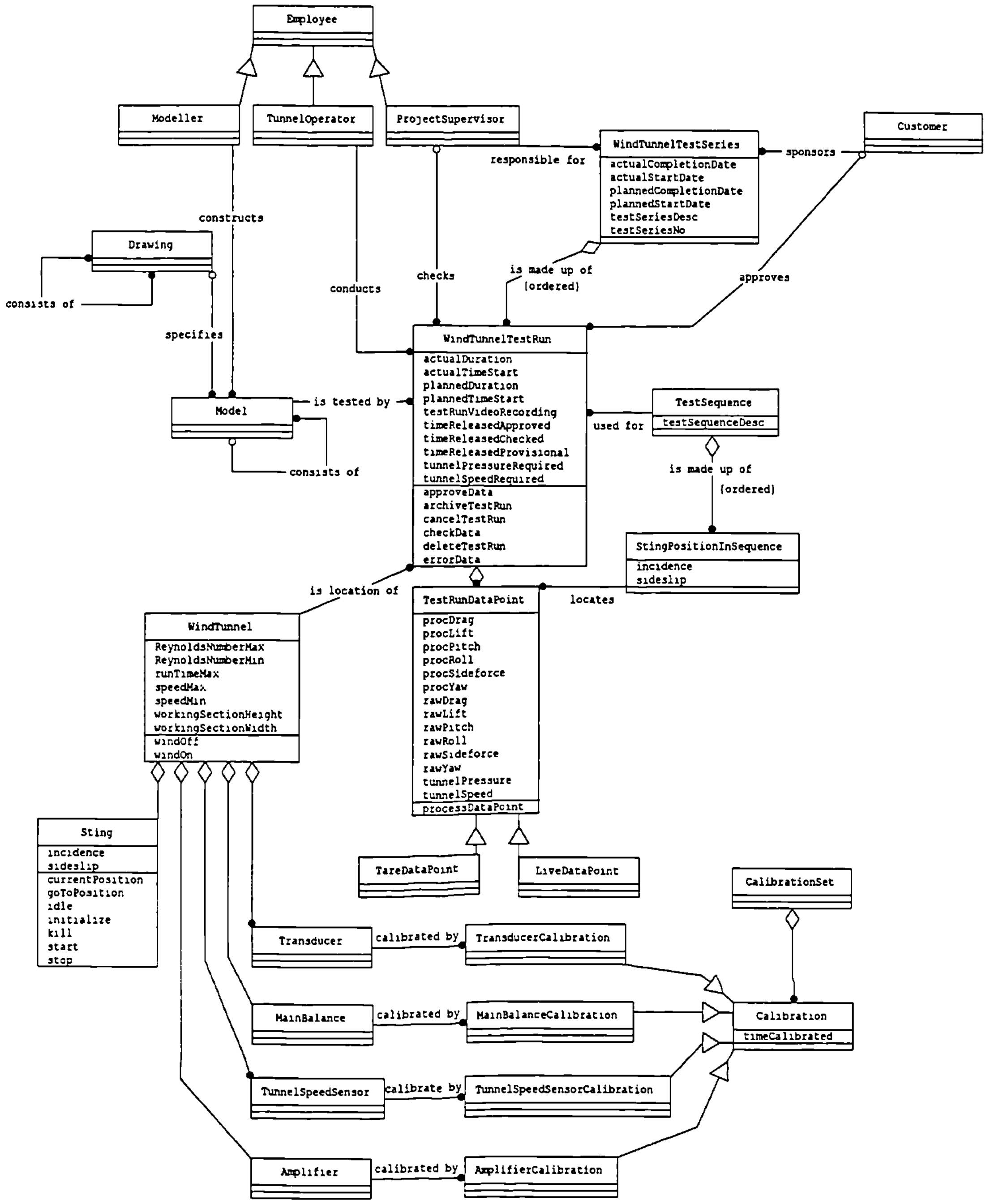


Figure 6.19: object model fragment for WTD

In the third section of the object type box are the methods that the object type has implemented, such as approveData which would be invoked by the customer to change the status of the test run from checked to approved. In the OO paradigm, the only way of getting an object to do something is to send it a message - how the object performs the requested task is hidden from the sender of the object. This is known as encapsulation and one benefit is that the implementation details of an object type can be changed independently of other object types, just as long as the external interface to the object type is unchanged. State transition diagrams should be produced for each of the object types and methods attached to the object types to handle each possible state transition.

The object model describes the product produced by WTD and provides a basis for implementing the product in a computer system as data structures. As with the process model, the object model in the context of the WTD faces in two directions, providing a description of what is to be delivered to the customer and forming a basis for building information technology.

6.4.3 Summary

The Process module of the ISDM/Q defines the processes and data that are needed to meet the requirements of WTD customers. The definition of the object model is, in the WTD scenario, the same job as defining the product. The object model in figure 6.19 shows the complexity of this product - test run data points are only useful if the context in which they were produced is known reliably, particularly the model and tunnel configuration. This is the province of traditional systems analysis (whether it be structured methods or OO Analysis), the aim of which is to develop a logical model of what is to be done.

The next section considers the interests of those whose job might be affected by changes in processes and the introduction of new computer systems.

6.5 Socio-technical analysis and design

This module of the IS quality methodology is concerned with those whose job design is affected by the implementation of new or redesigned processes, whether accompanied by new computer systems or not. The usual way of assessing the success of socio-technical design is to conduct a job satisfaction survey (Mumford 1983). This parallels the idea of customer satisfaction that was assessed using demanded quality questionnaires above. The primary users of R17 software are tunnel operators and project supervisors. To understand the nature of wind tunnel work, the author conducted a number of interviews with WTD personnel, from both the LSWT and HSWT. This was followed up by spending time in the wind tunnel control room observing tunnel operation.

6.5.1 The wind tunnel control room

The wind tunnel control desk is shown in figure 6.20. There is a striking mix of interfaces to the different parts of the wind tunnel system; for example, there are three VDUs - a DEC VT420 which can be used to set the tunnel speed, an IBM PC model 56/SX that controls the sting, and a Sun workstation that runs the control sequence programme (CSP) and assembles the unprocessed test run data prior to transmission to the mainframe. To the rear of the control desk there is another DEC VT 420 that performs mainframe emulation, a graph plotter, a laserjet IIId printer, a new PC, and a cabinet containing the PROSIG hardware. In between the control desk and the observation window a high-resolution video monitor is to be installed, mounted on an articulated arm. This monitor will provide customers visiting the tunnel top and side views of the model in the tunnel. The video camera and recorder are high-resolution, professional standard, with a zoom facility. This visual medium supplements the numeric forces and moments data and customers can be supplied with a copy of the test run videotape. It would be a relatively small step to make the contents of the video monitor available in real-time at remote sites, subject of course to network capability and appropriate hardware and software at the customer site.

6.5.2 Executing a test run

6.5.2.1 Model set-up

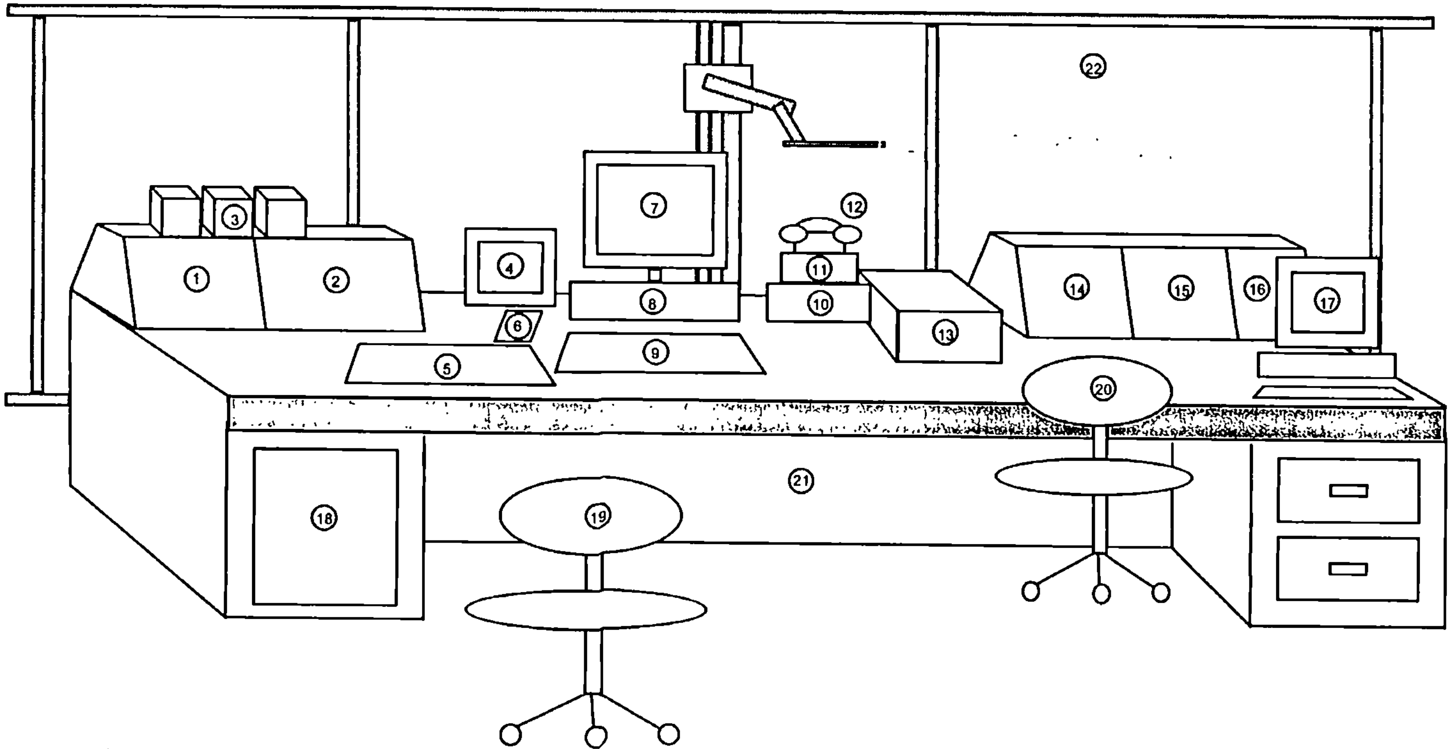
The model to be tested is configured to the test specification and placed in the model space in the tunnel (item 22 in figure 6.20). A test series typically involves a number of test runs in which one variable is changed at a time. Model configuration changes are made in between test runs by the supervisor and operator. Although the customer has specified the test runs required, the operator and supervisor use their experience to plan the actual order of the test runs, so that the complexity of the changes to the model configuration are minimized. For example, it is better to place the store on the model and run a number of tests using differed tail-flap elevations than to be taking the store on and off the model while keeping the tail-flap elevation constant.

Model configuration changes are delicate and require considerable experience, involving changes to model components, such as a flap setting, which might be checked manually using a bracket set to the required angle. Fine adjustments are also made through the application of materials such as sellotape and bluetak to achieve the desired flow characteristics. These fine adjustments are needed to cover up minor imperfections in the model, such as screw heads and small gaps in the wing. In all, it can take between half an hour and an hour to make a significant change to the model configuration. By minimizing the number of major model changes the operator and supervisor can greatly improve tunnel throughput.

The planning of the test run sequencing is a manual activity that requires considerable familiarity with model configuration and tunnel operation. The rational view, based upon customer requirements and process modelling, might be to execute the test runs in the sequence specified by the customer. However, this approach would be likely to be counter-productive since tunnel throughput would be diminished. Understanding of how work is actually accomplished is needed to assess the practicability of 'rational' process designs.

6.5.2.2 Running the test

The test run is controlled by a CSP (control sequence program), which is a C program that accesses a table of sting control parameters specifying alpha (incidence) and beta (sideslip) values. The R17 project is concerned with the development of the tunnel operation interface on the Sun work-station, including the creation and execution of CSPs. The R17 software must interface with all of the other tunnel control mechanisms, such as the Aerotech software that controls the movement of the sting. The R17 software must also gather together (assemble) the results of the test run once the run is complete, ready to pass the data to the mainframe. Processing of model data is performed currently on the mainframe, which means there is a delay in getting access to test run results and no opportunity for real-time display of processed test run data. There is, therefore, interest in transferring the data processing suites to the work-station environment (this is not part of the scope of the R17 project).



1 fan monitor - red LCDs
2 compressed air monitor - red LCDs
3 video monitors - 3 x 10 inch
4 DEC VT420 monitor - tunnel parameters, e.g., tunnel speed
5 keyboard for VT420
6 intercom keypad
7 SUN work-station monitor (20 inch)
8 SUN UNIX processor
9 SUN keyboard
10 tape drive
11 500 mb hard disk for Sun
12 telephone
13 8.4 gigabyte hard disk for Sun
14 milliVolt dials for strain gauge forces and moments readout
15 manual model attitude control for main balance
16 tunnel pressure read out
17 IBM PC for Aerotech software - sting control, mechanical balance control, forces and moments
18 power supply controls - light ing and other devices
19 project supervisor's chair
20 operator's chair
21 control desk
22 observation window onto model space in WT

Figure 6.20: the wind tunnel control room

Before the R17 prototype software was available the model was moved manually by the operator using item 15 on figure 6.20; this manual operation has been automated through the introduction of a CSP. It is tempting to envisage everything being centralized on the Sun work-station (item 7 on figure 6.20). However, observation of tunnel operation indicates that the current diversity of VDUs and panels has the benefit of allowing operators and supervisors to monitor and perform different tasks while a test is in progress. It would seem likely that three VDUs would be needed if processing was centralized onto work-stations: one for the operator to monitor the test run, another for setting up subsequent test runs, and a third for customers/visitors to monitor test run results.

When a test is executing, the WT personnel are monitoring the tunnel and model by observing VDU readouts, LEDs, and dials. They also listen to the sound of the tunnel and over time become sensitive to subtle changes to the noise made by the tunnel that may indicate a problem with the test run (perhaps a bit has fallen off the model or the tunnel speed has changed). They are also sensitive to the smell of the tunnel, such as burning wood which might indicate that something was rubbing in the tunnel. Although the R17 software might well be able to trigger various alarms on screen (audible as well as visual warnings) it is quite possible that the tacit knowledge experienced operators have built up over a number of years would be difficult to build into software. This all points to the need for caution when automating work that on the surface might seem quite straightforward.

6.5.3 Procedures

The WTD has come under pressure to document and apply detailed procedures in order to achieve third party ISO9000 accreditation. In response to a quality audit a manual log book has been introduced in which events occurring during a test run are recorded. The operator will record any unusual events and ad hoc actions, such as placing a piece of plasticine on the model (this would be documented with a sketch of the model showing the placement of the plasticine). This log could be held on-line and made available to the customer, possibly through groupware such as Lotus Notes, in order to fulfil two purposes: firstly to provide an audit trail of what was done, and secondly to inform customers of the status of their test runs and any unusual events or useful information that will help them interpret the final data.

6.5.4 Skills needed to operate the wind tunnel

Practical skills in tunnel operation are learnt on the job. There is formal training, but this tends to deal with the theoretical aspects of wind tunnel testing. According to a project supervisor and an operator the characteristics of a good operator are:

- methodical;
- takes accurate notes;
- can spot unusual situations;
- good with hands - for making adjustments to the models (a mechanical engineering background helps).

The respondents considered that it would take about two years to become proficient in wind tunnel operation. This is partly due to the time it takes to gain experience of the different types of model that are used, such as intake models.

6.5.5 Summary

In listening to WTD customers and developing process models we create a view of the WTD that reflects organizational requirements. This is typically a rational view of what the organization should do. This view must be contrasted with the socio-technical view that considers how work is actually accomplished. Perhaps the most appropriate way of doing this, short of doing the work oneself, is to observe work being done and to ask questions. The use of prototyping methods is a powerful way of developing software insofar as it surfaces the details of work that cannot be guessed at by traditional process modelling approaches.

6.6 Design of technical artefacts

The technical module is concerned with the design of technical artefacts that will automate aspects of the process and object models. Even though we might develop process models to meet requirements in all areas of the high level process model presented in figure 6.16, it is unlikely that it will be possible or appropriate to build computer systems to support all of those processes. However, some of the object types and processes will be supported by computer systems and in the technical design module attention is turned to technical artefacts.

In the case of the WTD the software development exercise was approached using an iterative development life-cycle. The R17 developer created successive prototypes and sat with the tunnel operators in the wind tunnel while they used the software. Once the software had been 'tested' in the wind tunnel it was then put through a software QA process and packaged into a release. A new release was being produced every two or three months as new functionality was added into the software. This approach was excellent insofar as the users got what they wanted and could establish their requirements incrementally. On the downside the software design was hard to pin down since the approach was bottom-up from the programming. After the first few releases the scope and feel of the software stabilized and a more rigorous, formal, and thorough design specification was produced.

The users were delighted with this approach because it meant that they saw what they were getting very quickly and could change their minds. The alternative was for Ground-Based Systems, another part of the BAe development organization, to create the R17 software following a traditional waterfall life-cycle. The comment from the wind tunnel personnel was that that takes a long time and when they get the software it is not usable because it was created without the benefit of practical experience of using the software. The prototyping approach adopted on R17 was also useful because it allowed the scope of the project to be changed relatively easily; for example, a real-time, graphical data read-out was added to the operator's interface. This was useful to aerodynamicists, but not fully since only pre-processed data was available on the work-station - the processing suite that provided fully usable aerodynamic data was still mainframe-based.

6.7 Exiting the action research situation

The perception of the WTD and Technical Computing was that the author would play a low-key role in the R17 project; attending steering committee meetings and conducting interviews. As the project progressed and the ISDM/Q was developed the level of intervention increased. The WTD personnel and aerodynamicists made more time available and what started as an academic exercise took became meaningful in terms of WTD computing strategy and the future of the R17 project. A report was produced of the research phase and a presentation made in November

1995 to WTD and Technical Computing personnel. Despite the early scepticism about the wide scope taken by the author the benefits of placing software development in a wider organizational context and listening to customers had been demonstrated. The sponsors of the project met to decide how to pursue the ideas developed in the research project and are considering how the method, or parts of it, might be instutionalized within BAe.

Chapter summary

The application of the ideas and methods proposed in the provisional form of the ISDM/Q has been described in this chapter. The practical application of the ISDM/Q centred on the analysis of organization and QFD modules, which contain the innovatory elements of the research. Although there was less practical work carried out in the process modelling and socio-technical modules, enough was done to gain some useful insights. The technical design module was outside of the scope of the researcher, but interviews of the system development staff were conducted in order that the role of design could be studied. Through the action research the broad ideas of the provisional ISDM/Q were given substance. In the next chapter the author will reflect upon the action research in terms of the lessons learnt about the area of application (A) and the methodology (M), leading to the evolved form of the IDSM/Q.

7

Reflections on the evolution of the ISDM/Q

Introduction

The action research described in chapter 6 constituted phase 3 of the fieldwork. In this chapter the fieldwork is reflected on in terms of the methodology (M) and the area of application (A). The learning presented in this chapter is mainly at the level of the content of the methodology and the application of the various techniques reported in chapter 6. As such, it represents first order learning and is close to the practice of IS development. In chapter 8 the fieldwork will be considered with respect to the learning made about the framework of ideas (F) and IS development and quality in general; this will represent second order learning and will be more relevant to the theory of information systems and information system development.

The structure of this chapter is as follows (figure 7.1): in the first section lessons are drawn from the analysis and design modules of the ISDM/Q and in the second section lessons from the use of QFD; in the third section the methodology is put together such that it can be used in chapter 8 as a basis for evaluation of the framework of ideas (F). The evolved form of the ISDM/Q together with the lessons learnt are summarized in table 7.1.

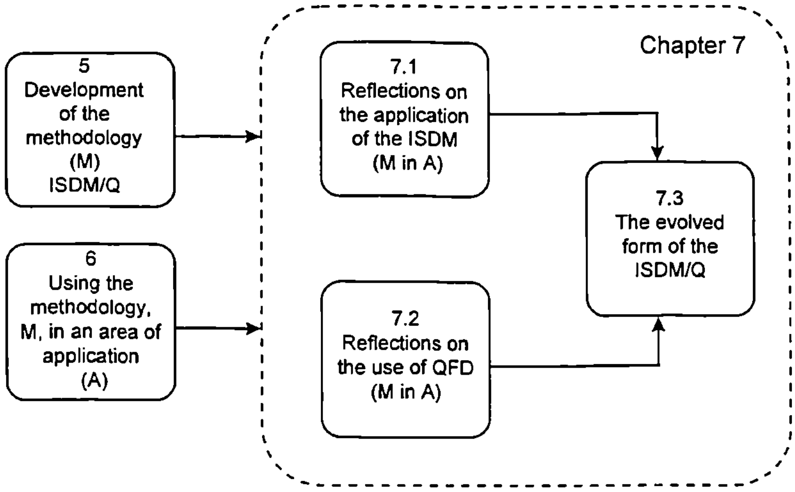


Figure 7.1: structure of chapter 7

7.1 Reflections on the analysis and design modules

7.1.1 Analysis of organization

The provisional form of the ISDM/Q described in chapter 5 contained two activities: stakeholder analysis (SAST) and soft systemic modelling (SSM). As the action research unfolded four aspects of the analysis of organization emerged (figure 7.2). Systemic analysis was conducted in parallel with gathering quality requirements and it proved useful to contrast the conceptual formulations of SSM with the real-world verbatims of customers. Stakeholder analysis was used, together with rich pictures to understand and analyse the current situation, which could be contrasted with possible futures, taking account of the possible impact on current and new stakeholders and the potential affects of technology. It helps to think of all four views as being connected; for example, stakeholder analysis (situational analysis) and systemic analysis (conceptualization) inform each other.

Double-headed arrows have been used purposely in figure 7.2 as the four analyses are co-present and co-dependent - there is no inexorable flow from current situation to future situation and neither is there a complete separation of conceptual world and real-world. For example, by thinking about possible futures we can re-interpret the current situation; thinking conceptually with SSM can help in the interpretation of real-world customer verbatims. In this sense the aim of organizational analysis is to achieve a temporary separation of the analyses that will provide sufficient stability for purposeful action.

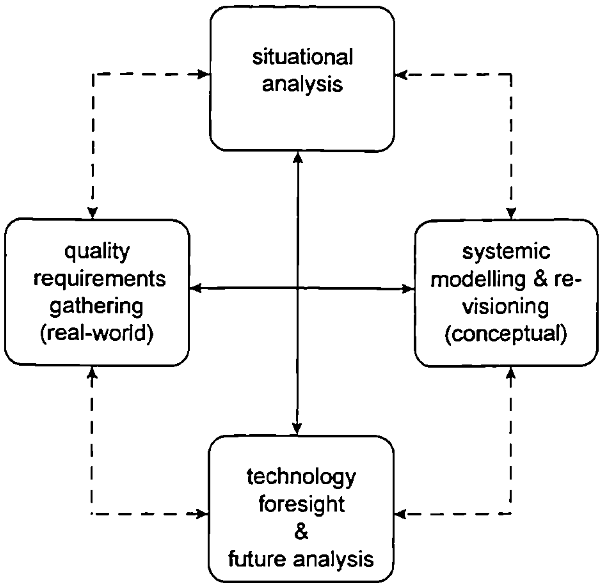


Figure 7.2: the analysis of organization module

The techniques employed in the analysis of organization are now considered in turn and lessons drawn from the fieldwork.

7.1.1.1 Stakeholder analysis

Creation of a rich picture and stakeholder analysis are the primary techniques used in situational analysis. As already noted, stakeholder analysis impacts all areas of the analysis of organization module: current stakeholders are identified in situational analysis and the impact on stakeholders, including new stakeholders, is considered in the future analysis; when creating systemic models stakeholders provide a basis for discussing the relevance and implications of the systemic model; those stakeholders that are considered to be customers then become the subjects of real-world quality requirements gathering.

However, in practice problem situations that are perceived to be complex can result in a large number of stakeholders being identified - it is not difficult to find upwards of thirty stakeholder groups. To consider all of the stakeholders' quality requirements would quickly become intractable. Mitroff & Linstone suggest that a graph of importance versus certainty be used (figure 7.3), with attention being focused on stakeholders that are placed in the important/uncertain quadrant.

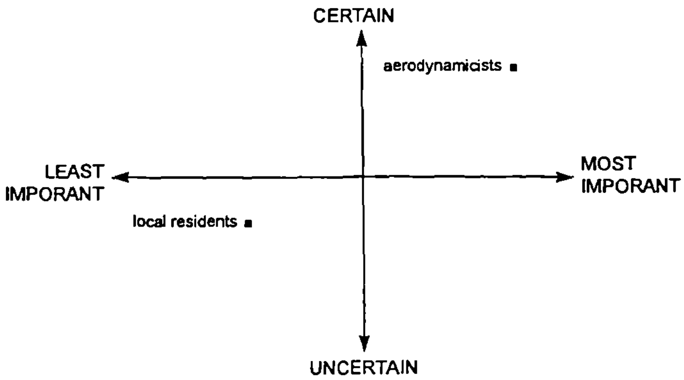


Figure 7.3: stakeholder assumption rating

Clearly, some basis for selecting stakeholders for further consideration as customers is needed. The stakeholder assumption rating graph is used by Flood (1995) who provides some useful guidelines for thinking critically about stakeholders and how they might be affected in the context of the goals of the intervention and discussion concerning who should benefit (p.218). Other selection criteria might include: closeness to the IS (primary users, users of system output, etc.); those likely to be disadvantaged; perceived power within the organization (e.g., senior management); and control of budgets (e.g., Finance department). Selecting the 'wrong' stakeholders for participation in the gathering and analysis of quality requirements could result in an IS development project failing if the omitted stakeholder group is particularly powerful or essential to the process the IS is supporting. It is also possible that an IS development project could be deemed to be successful by the dominant stakeholders but at the expense of other, possibly marginalized, stakeholders.

The author has extended stakeholder analysis to include non-human stakeholders. The intention of doing this is to keep technology present throughout the analysis of organization module and is motivated by the body of work comprising actor-network theory described in chapter 4. The inclusion of non-human stakeholders will require considerable further research to explore the implications for stakeholder analysis, soft systems modelling, and even quality requirements gathering.

7.1.1.2 Soft Systems Methodology

SSM is typically learnt as a mode 1 seven-stage cyclical process. But, as the author found out, applying SSM in this manner is likely to be ineffective and, as with any methodology applied over-zealously, may damage an IS development project as participants resist alien language and unfamiliar ideas. It might be argued that the solution lies in the provision of training in SSM for those involved in an IS development. This would have not been possible in the action research environment of this research and neither, the author believes, would it have been effective since, to put it in SSM terms, such training would not have been perceived as being meaningful.

Checkland (1995) in later work seems to be moving away from the technical systems approach of mode 1 analyses:

> With increasing experience and sophistication among users of SSM, the use of the formal system model has declined, and in the most recent account it is 'cheerfully dropped' (Checkland and Scholes, 1990, p.42). The question of technical validation is now faced by asking whether a pairing of root definition and model is defensible. (p. 53).

However, it takes a relatively long time, in the author's opinion two or three years, for the concepts of SSM to become sufficiently internalized for the analyst to apply SSM effectively in mode 2. To use SSM effectively the practitioner needs to be using the ideas as a natural way of being in the world, adapting to the situation as it unfolds, but the same comment can be made about most powerful techniques used in IS development, such as data modelling (de Carteret & Vidgen 1995, p. 3).

In the context of the action research the root definition and CATWOE were found to be of most use, particularly the Transformation and Weltanschauung elements. The concepts of Transformation and Weltanschauung were simplified to the basic propositions of purpose - *what* (Transformation) might be done - and motivation - *why* (Weltanschauung) it would be meaningful. This reminded the author to ask continually why things are done now and allowed conceptual SSM models to be presented back for debate using a vocabulary that was meaningful to *both developers and users.*

Conceptual models (CM) were developed in the action research, although these were perhaps not as useful as the root definitions (RD). In SSM RDs and CMs tend to be treated as inseparable and in the early exposition of SSM Checkland (1981) argued that the conceptual activity model must be derivable from, and consistent with, the root definition. Within a hierarchy of systems the *how* of one level constitutes a *what* at the next lower level of resolution (Checkland 1981), with *hows* at any given level being expressed through CMs. Mingers (1990) states:

> However, I would argue that there can never be a completely specified expansion of an RD into one and only one CM, unless the RD explicitly includes all the main activity verbs, in which case it could be argued that it is specifying a how anyway. (p. 23)

Mingers (ibid.) concludes that:

> ...the *what/how* hierarchy lies in a different dimension to the levels of resolution of a conceptual model. For each level in the former, there will be a range of CMs reflecting the different possible *hows*. Resolving any of these CMs does not take one down a level, but increases the amount of detail at that level. (p. 28)

For the current author this means that the conceptual models of SSM are in fact a functional decomposition. The implications of this are that perhaps conceptual models are not particularly useful since we could replace them with the richer and less ambiguous notations of traditional systems analysis or with a more strongly systemic basis for modelling activity, such as Beer's (1981, 1984) viable system model (VSM).

Although it might be a gross over-simplification of SSM, it seems to this author a large part of the value of SSM is in establishing novel, imaginative, and interesting Transformation and Weltanschauung pairings. If the root definition is mundane then the activity model that is generated resembles too closely the real-world situation and the opportunity for insight is diminished. Unfortunately there is nothing in SSM that can help the developer with the content of the root definition - as with any technique the content has to be supplied by the analyst.

7.1.1.3 Quality requirements workshops

The quality requirements workshops described in chapter 6 were introduced as a way of finding out what customers required. To support the QFD activity it is essential that non-functional requirements and qualities are gathered as well as the functional requirements that tend to be the primary concern of developers. On reflection the author would recommend that these workshops are used to capture functional and non-functional requirements at the same time; these can be interpreted, analyzed and separated for the purposes of QFD as part of the quality planning and quality deployment activities.

From the action research it quickly became apparent to the author that for requirements workshops to be effective an expertise in facilitation is needed. The need for these types of skills tends to be down-played in IS development, possibly due to the engineering orientation of many developers. The role of the facilitator is defined by Macaulay (1996) as 'concerned with assisting the other group members in performing their collective task as a group' (p. 93). Macaulay (ibid.) lists a number of problems that may arise in facilitation, including: 'multi-headed beast' syndrome, which is manifested by symptoms such as digressions, interruptions, and no listening; 'dominant species' syndrome, typified by unequal air-time and passive/aggressive body language; and 'sleeping meeting' syndrome, with symptoms including long silences, absence of ideas, and withdrawal (p. 95). The author's experiences of conducting workshops point towards the need for training in facilitation skills and/or the use of professional facilitators. To rely entirely on 'learning on the job' is time-consuming and potentially damaging to the credibility of the IS development organization.

7.1.1.4 Technology foresight and future analysis

Technology foresight is included in the analysis of organization module to ensure that technology is kept present when considering the organizational requirements of an information system. Technology can be distinguished from technical artefacts, which are an instantiation of one or more technologies. For example, relational database management systems are a technology, while a copy of IBM's DB2 running on a particular organization's mainframe is a technical artefact. Thus there is a difference between a specific computer-based technical artefact, which comprises a concrete collection of technology instances and has some emergent functionality, and a technology which is an abstraction.

The aim of including technology foresight is to consider the possible impact of technologies such as video-conferencing, virtual reality, multi-media databases, and so on. Although one might argue that technology need not be considered in the analysis of organization, this author holds that it is important to do so since technology can enable new forms of organization and new activities that would be either unthinkable or unmeaningful without the technology. For example, Vidgen (1994) has described a scenario for a vehicle rental company in which technology such as video-conferencing could be used to reduce the number of car hires that an organization might need to make.

Future analysis is closely related to technology foresight but focuses on stakeholders - human and non-human. As a result of an intervention such as the development of an IS stakeholders will be affected; some might disappear and new stakeholders will emerge. Future analysis is thus concerned with the development of scenarios for possible futures supported by possible uses of technology.

7.1.2 Process modelling

In the action research, analysis of the demanded qualities showed that the aerodynamicists expected that the WTD would have processes that address the following areas:

- *operations*, e.g., quality 1 in figure 6.11, 'can schedule test series to meet project timescales';
- *service*, e.g., quality 10 in figure 6.11, 'has staff who are conscientious and open';
- *infrastructure*, e.g., quality 20 in figure 6.11, 'has a variety of modern WT facilities'.

Generic process models can be found in the supply chain management literature (Hewitt, 1995) that address supplier, manufacturing, logistics, and customers. The generic process model that has evolved from this research suggest that any business unit consider the following (figure 7.4):

- *Strategy*: understanding the organizational context in which the business unit is operating. This requires constant monitoring of the environment to detect and understand changes taking place in the context that may affect what the business unit does and how it does it. This process must be sufficiently sensitive to avoid the boiled frog syndrome. (If the water temperature is increased gradually the frog cannot detect the incremental changes and boils to death. If the frog was placed in hot water then it would jump out. Business units must be able to detect small changes and understand the cumulative affect of sequences of, possibly, small changes if they are to avoid being boiled frogs.);

- *Operations*: this set of processes are core to what the business unit does. Strategy is concerned with what is to be done and why, operations with how, who, and when. The principal elements of operations are manufacturing and logistics - making a product and getting it to the customer. The product can be tangible or intangible;
- *Service*: service processes focus on the customer: keeping the customer informed, understanding their quality requirements at a detailed level, monitoring customer satisfaction, and so on. This tends to be an informal (or non-existent) process in many organizations. Some degree of formalization of service processes is appropriate regardless of what the product is since it is quite possible for customers to like the product but to hate the service;
- *Infrastructure*: a business unit requires support functions, such as finance, human resource management, facility management, and computer systems development. Where these processes are not considered to be core to the business units purpose then they become primary contenders for outsourcing.

Whether the product be physical, such as a wiring loom for EFA, or data is immaterial; in the case of the WTD the product is data and it is distributed through computer networks. The metaphor of manufacture and logistics is therefore not inappropriate for the WTD. The quality requirements workshops identified three of the process types in figure 7.4, but not strategy. It is perhaps not surprising that customers might not ask for this specifically, in which case strategy should be a supplier-initiated set of processes, especially if the supplier wants to survive in the longer term.

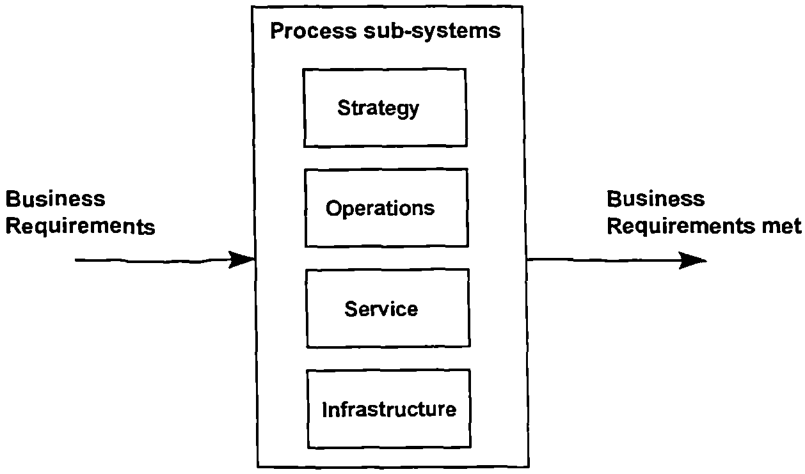


Figure 7.4: generic business processes

7.1.3 Socio-technical analysis and design

In theory approaches such as ETHICS and user-centred design should result in "better" information systems. In practice these methods have not experience widespread uptake, due in part to the level of resource and commitment required. Although Ehn & Kyng (1987) suggest that designers spend 'at least a year or two getting acquainted with a new area' this is unlikely to be acceptable in practice. In the action research the author spent two half days observing the operation of a wind tunnel, which although clearly a drop in the ocean in Ehn & Kyng terms resulted in a dramatic increase in the author's understanding of the work to be automated through IS development. In many IS development projects the separation between users and developers is such that communication is limited to interviews and source document review. At best this allows the developer to document an espoused view of how work is accomplished.

It is therefore proposed that the socio-technical module consist of two activities: understanding how work is actually achieved (Sachs 1995) and socio-technical design. Even if it is not possible to conduct formal socio-technical design any practical understanding of how work is accomplished will be of benefit.

7.1.4 Design and construction of technical artefacts

In the R17 project software was developed and used immediately by the tunnel operators, reflecting an evolutionary approach. Once a package of software functionality had been agreed then it was put through a software QA process following which it could be released officially. Thus, the software development process for R17 is characterized by evolutionary development combined with iterative development for the purposes of software quality management - the life-cycle models of figure 2.3 b and c are being used. This is an interesting combination since it provides a way of addressing the tension between the customer's demand for software that is usable and helps them in accomplishing their work with the supplier's desire to build 'quality' software that has attributes such as testability, maintainability, reliability, and so on.

A more general extension to the Technical module proposed in the provisional ISDM/Q presented in chapter 5 is to extend the scope of the module to include not only design but also construction of technical artefacts. This becomes necessary once when moves away from the espousal of waterfall life-cycles and more particularly by the recognition that design and construction are inseparable (Budde et al. 1993).

7.2 Reflections on the use of QFD

In the action research the use of QFD was focused on the preparation of a quality plan (figure 6.11), carrying out a design of QFD matrices (figures 6.12, 6.13) and completing drafts of the A1 matrix (figures 6.14, 6.15), including documentation of demanded qualities (appendix C) and quality characteristics (appendix E). QFD was, therefore, used primarily in the narrow sense of quality planning and quality characteristic identification.

7.2.1 Quality planning

The quality plan was constructed from the diverse set of customer verbatims gathered during the quality requirements workshops. These had to be interpreted and condensed into a usable set of demanded qualities. It was particularly useful to have customers prioritize the qualities using a questionnaire since this was an opportunity to assess current levels of satisfaction with the WTD's performance and to gain an insight into competitor performance. Given that the primary aim is of TQM is to improve customer satisfaction this would seem to be an area that could have significant implications for IS development, particularly in the areas of assessing IS effectiveness and evaluating IS investments through post-implementation reviews.

Admittedly there is a lot more work entailed in developing a situation-specific quality plan, but the author argues that it will be a more valuable guide to customer satisfaction than the generic user-information satisfaction instruments described in chapter 2 (Bailey & Pearson 1983).

7.2.2 QFD design and quality deployment

It was noted in chapter 5 that the broad form of QFD emphasizes deployment into parts, functions, and processes. A QFD design specific to *information systems and* the particular area of application was made (figure 6.15) and could be used informally to remind the developer to consider the relationships between the different elements of the information system development process. When used formally this series of matrices should result in measures for different aspects of an information system, including processes, object types, and software. In the action research it became readily apparent that it would not be possible to conduct a full QFD analysis. Likely reasons for this are:

- a full application of QFD is a time-consuming and labour-intensive process;
- it must involve personnel from all aspects of the supplier department and preferably customer representatives;
- there must be defined processes in the supplier department if the connection between demanded qualities and software quality is to be made.

In the WTD the analysis of customer requirements was a significant step toward a quality approach to information system development, but the level of commitment and resource needed to follow it through would be beyond the scope and the timing of this research. Although we did not use QFD formally to drive high level customer requirements down in to software characteristics it was possible to make the connections informally; for example, once it was recognized that aerodynamicists needed real-time data then the software could be modified accordingly.

It seems likely that for projects being conducted in an environment where quality management is not sufficiently strong to support formal QFD then the matrices of figure 6.13 can still be used as an aide memoire for considering the interactions between customers, processes, and technical artefacts (figure 7.5). Thus although the author prefers to view IS development as mediation between the four analysis and design modules, IS/QFD provides a rigorous and systematic of rationalizing the connections between:

- customers and products (why organizational activity is performed);
- business processes (how organizational activity is carried out)
- technical artefacts (technological support for business processes)

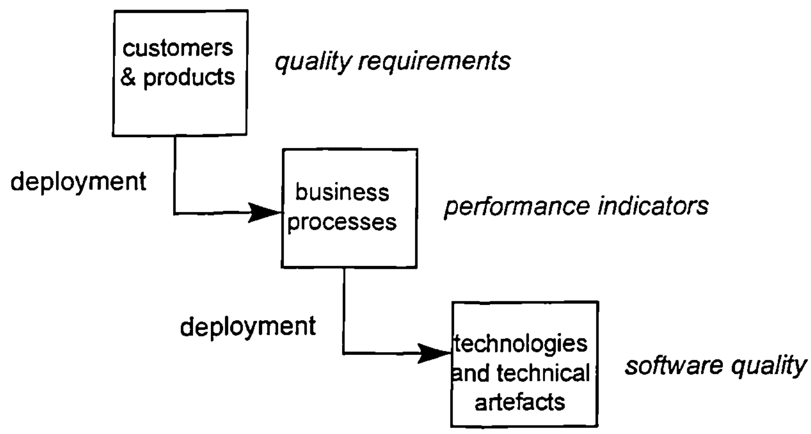


Figure 7.5: information system quality function deployment (IS/QFD)

Finally, it is worth noting that learning to use QFD was a long and difficult process for the author. As with other methods of IS development, such as SSM and data modelling, it is one thing to learn the notation and mechanics but quite another to attain a practical competency, which can only be gained through time and experience.

7.2.3 A note on software quality

Although software metrics are outside the scope of this project the author believes that it is important to show how IS quality might be driven down to the level of measuring attributes of software. Software will support processes and object types defined in the process modelling module. These processes and object types have been tied to customer(s) quality requirements through IS quality deployment, particularly through matrices D1 through D4 which are concerned with deploying process modelling, technologies, and socio-technical requirements into technical artefacts. Also, the software must meet the technical demands of the development process - the supplier's view of quality.

Software quality Matrix A1			Quality characteristics											
			Fault counts			Degree of testing			Effort		Change counts			
Demanded qualities		demanded weight	Closure time	Isolate/fix time	Fault rate	Statement coverage	Branch coverage	Test plan completeness	Resource prediction	Effort expenditure	Change effort	Change size	Change rate	
Maintainability	Analysability	14	+	O	+									
	Changeability	19							O	O	+	O		
	Stability	23							+	O		^	+	
	Testability	44				O	O	+	O	^				
		total	126	42	126	132	132	396	396	170	171	80	207	1978
		percent	6	2	6	7	7	20	20	9	9	4	10	100
		plan												

Figure 7.6: software quality deployment

The ISO9126 standard specifies quality characteristics, although stops short of specifying a set of metrics to accompany those characteristics. For illustrative purposes, figure 7.6 shows how a characteristic such as maintainability, which ISO9126 sub-categorizes into analysability, changeability, stability and testability, can be mapped into software metrics. The metrics are taken from Fenton (1991), as have the relationships in the matrix, although these needed further elaboration by the author. The demanded weight should reflect the view of the customers (software users) and suppliers. Each of the quality characteristics should be assigned a target value, this being a measurable characteristic of the software product. In this way, software metrics can be grounded within a context that takes account of the different demands placed upon it by the business context, software users, software developers, and technologies.

7.3 The evolved form of the ISDM/Q

In chapter 5 the provisional form of the ISDM/Q was presented with the following extensions to the Multiview methodology:

- stakeholder analysis has been introduced to complement SSM and the Multiview "human activity" module renamed "analysis of organization";
- structured methods have been replaced with Object-Oriented analysis and the Multiview "information analysis" module renamed "process modelling";
- the range of socio-technical options has been extended.

Following the action research described in chapter 6 and the lessons reported in this chapter the following extensions to the ISDM/Q are proposed:

- the idea of mediation is adopted as the organizing principle for the IS development methodology (discussed further in chapter 8);
- the role of multiple perspectives is applied to the process of IS development as well as to the content of the methodology - the IS development should be seen through the Organizational and Personal perspectives as well as the rationality of the Technical perspective (TOP) (discussed further in chapter 8);
- non-human stakeholders are introduced in order that technical artefacts and other non-human stakeholders can be incorporated in the analysis of organization;
- future analysis and technology foresight are introduced to the analysis of organization module;
- the range of the technical design module is extended to include the construction of technical artefacts - this is needed to accommodate iterative and evolutionary development approaches where design is completed during construction.

The above modifications to the Multiview methodology represent the ISDM component of the ISDM/Q; TQM methods are integrated into the development cycle through the use of quality function deployment (QFD) to provide a total quality approach. The process of IS development is pictured as an exercise in mediation whereby each of the four analysis and design modules of the ISDM/Q informs and shapes the others.

A significant role for QFD in mediatory IS development is to provide the (post-) rationalization, audit trail, and management control that are needed on complex IS developments involving many people and parts of an organization (figure 7.7). The author does not suggest that QFD *is* a rational means-ends process of turning customer requirements into software product characteristics, rather that it can be used as an organizing framework for information system development once we have given up the pretence of waterfall life-cycle rationality. Thus although the requirements might not be known until an information system is being used, the on-going approach of QFD would allow IS developers to develop continually their understanding of customer requirements as well as their understanding of the relationships between customer satisfaction and specific characteristics of the IS. This would require that developers continue to monitor customer satisfaction throughout the life and not just in the initial construction phase.

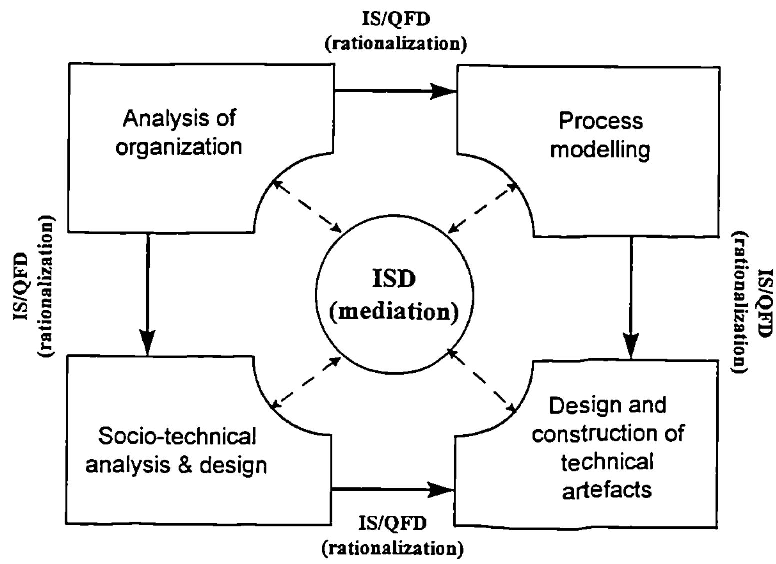


Figure 7.7: overview of the quality approach to IS development (ISDM/Q)

Chapter summary

The learning from applying the ISDM/Q via action research has been described and a range of further additions to the provisional ISDM/Q of chapter 5 have been proposed. Key conclusions were that IS development should be approached through a metaphor of mediation and that IS/QFD can be used to (post-) rationalize the development process and to provide a structure for managing and documenting the outcomes of mediation. In table 7.1 the evolved form of the ISDM/Q is summarized. The various lessons that arose from the action research and described in this chapter are included in the final column.

Module	activity	approach	deliverables	outcomes	lessons from the research
analysis of organization				shared understanding of the problem situation	• contrast current and future situation, conceptual and real-world; • consider organizational and technological issues and implications jointly
	situational analysis	conduct interviews; review source documents; surface, challenge, and test assumptions about stakeholders	rich picture plus other appropriate diagrams (e.g., DFDs); stakeholder map; analysis of assumptions about stakeholders	understanding of the current situation; understanding of who the stakeholders are and how they can affect (be affected by) the proposed intervention	• include non-human stakeholders, such as technical artefacts; • make explicit the criteria for including stakeholders in quality requirements analysis
	systemic modelling and re-visioning	develop SSM conceptual activity models	root definitions, CATWOEs, and activity models	conceptualization and re-visioning of the situation a basis for debate concerning the proposed intervention	• focus on the T and W of CATWOE and the what/how hierarchy; • be bold and imaginative in re-visioning; • be sensitive to the language used to express SSM
	quality requirements gathering	gather quality verbatims of customers	documented 'voice of the customer'	raw understanding of what constitutes quality for customers of the product and/or service; a basis for drawing up a quality plan	• collect verbatims relating to qualities and functional requirements at the same time; • ensure that facilitation skills are available
	technology foresight & future analysis	consider the potential and impact of new technologies; consider impact of intervention on stakeholders	technology foresight analysis; stakeholder impact analysis	understanding of impact of intervention on stakeholders and input to organizational change programme	• distinguish between technical artefacts and technologies

Module	activity	approach	deliverables	outcomes	lessons from the research
process modelling				a shared understanding of business processes that can be communicated through the organization and enacted in software	• process and object models are not an end in themselves - they are enabling bridges between organization and technical artefacts
	business process modelling	event modelling	a set of functionally decomposed event schemas	a detailed understanding of business processes; a basis for functional design of computer systems	• a generic process model is a helpful template • define process measures to enable management and improvement
	business object modelling	Object-Oriented (OO) modelling of business object types	object model	understanding of the business objects used in the organization; a basis for design of class structures of computer systems	• the object model represents the developers view of the computer system and is a basis for design leading to re-use and flexibility
socio-technical analysis & design				balance of social and technical requirements	• be realistic about time and resource constraints
	work analysis	observation/ethnography	descriptions of how work is accomplished	a basis for design of work and computer systems reflecting how work is actually done rather than espoused	• always spend some time studying how work is achieved in actuality
	socio-technical design	ETHICS; user-centred design	design of work	trade-off of technical and social requirements mediated by technology	• prototyping does not in itself constitute socio-technical or participative design

Table 7.1: a quality approach to IS development - ISDM/Q

Module	activity	approach	deliverables	outcomes	learning from the research
design and construction of technical artefacts					• design and construction are not entirely separable (other than as an outcome)
	technical design	software engineering	logical design; physical design; construction	functional and non-functional requirements translated into a physical design	• try to separate the design from the software when conducting evolutionary development
	construction of technical artefacts	software engineering	computer-based technical artefact	physical design translated into a technical artefact	• try to separate the design from the software when conducting evolutionary development
IS quality function deployment (IS/QFD)					• QFD should aid in rationalization and management of ISD
	IS quality planning	translate the customer verbatims into demanded qualities; prioritize the demanded qualities according to importance as perceived by the customer	quality plan; demanded quality dictionary	establishment of a set of prioritized customer demanded qualities; assessment of current level of customer satisfaction; assessment of competitor performance	• never assume that you know what the customer wants • a quality plan is a situation-specific instrument for assessing customer satisfaction
	IS QFD design	establish a set of QFD matrices to deploy customer requirements through all aspects of IS development	QFD matrix design	defined inter-relationships between elements of IS development	• design of QFD matrices should be specific to the situation
	IS quality deployment	use the matrices to define measurable characteristics of the IS elements	quality characteristics dictionary; completed QFD matrices	a basis for systematic and on-going improvement of IS quality	• matrices are useful as informal guidelines for considering inter-relationships of IS elements

Table 7.1: a quality approach to IS development - ISDM/Q

8

Learning from the research and conclusions

Introduction

This thesis has been concerned with an investigation of IS quality and approaches to IS development that would be supportive of IS quality outcomes. A framework of ideas (F) was presented in chapter 4 and a methodology (M) developed in chapter 5. In chapter 3 action research was selected as the primary research method and in chapter 6 the experiences of applying and developing the methodology in an area of application (A) were described. Reflections on the action research in the context of the lessons learnt about the methodology and the area of application (M, A) have been made in chapter 7, resulting in an evolved form of the ISDM/Q. The first order learning of chapter 7 is supplemented in this chapter with the second order learning that results from reflection on the fieldwork in the context of the framework of ideas (F). Further aims of chapter 8 are to: evaluate the research proposition and the learning outcomes planned in chapter 1; reflect on the research process; evaluate the contribution of the research to theory and practice; and to establish areas of future work.

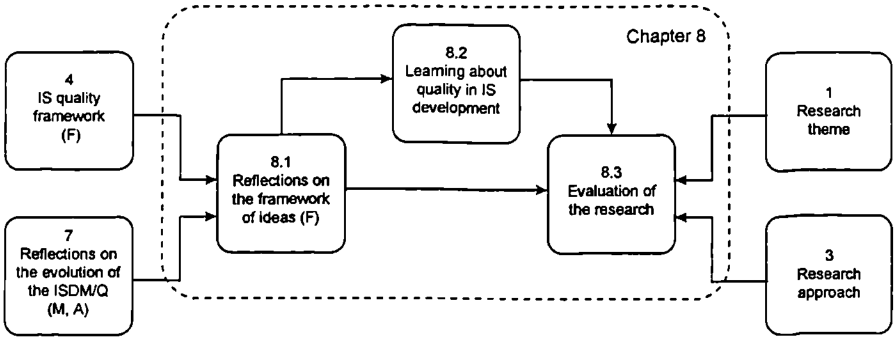


Figure 8.1: structure of chapter 8

The structure of the chapter is given in figure 8.1, which should be considered with reference to the thesis structure presented in chapter 1 (figure 1.5).

8.1 Reflections on the framework of ideas (F)

In chapter 4 a framework of ideas was presented, drawing principally from Linstone's work on multiple perspectives (section 4.3), Giddens' work on structuration theory (section 4.5.1), and Latour's work on actor-network theory (section 4.5.2). These are three distinct ways of looking at the world and have roots in rather disparate backgrounds: enquiring systems, sociology, and technology & society respectively. Common to all three approaches is an acceptance of the messiness and undecidability of action together with a disposition towards being suspicious of worldviews founded on deterministic ideas such as cause and effect. The three approaches all espouse the idea of inseparability: with multiple perspectives the Technical, Organizational, and Personal dimensions are inseparable and irreducible; in structuration theory action and structure are co-present; and in actor-network theory organizations and technology are considered to be two sides of the same coin. These three approaches are now used to interpret the fieldwork and to record the learning made with respect to the framework of ideas.

8.1.1 Multiple perspectives

In the action research the Technical perspective, T, to the R17 project was reflected in the aim to create software that could be used to operate the wind tunnels and communicate with the new data acquisition system (DAS). From an Organizational perspective, O, the project could also be viewed as supporting the restructuring of the wind tunnel department into a facility-based rather than a tunnel-based operation (appendix A, figure A.2). R17 was also an opportunity to improve the working relationships (O) between the wind tunnel department and the aerodynamicists, the primary customer for the aerodynamic data produced in the wind tunnels. Using a Personal perspective on R17, P, one might consider how an individual operator's job will change, which personnel might be promoted (or made redundant) if it is "successful", whether the developers will get performance-related pay, and so on. However, these three perspectives are not separable and although developers might like to pretend that the T perspective prevails, in many situations the view of IS development as technical rationality would seem to be the least effective way of explaining how a situation unfolded (Markus 1983).

Multiple perspectives were also used in the quality workshop held at Farnborough with aerodynamicists (section 6.2.3.1). In order that the attendees might not think too narrowly about their requirements of the Wind Tunnel Department (WTD) they were asked to think about T aspects (e.g., the test facilities available), O aspects (e.g., the way the departments communicate with each other), and P aspects (e.g., the attitude of WTD personnel). In a recent research situation the author found that the culture of the organization was such that only the T perspective was perceived to be meaningful; the attendees had a clear idea of what they wanted and did not perceive the O and P perspectives to be meaningful. This author would argue that O and P are always relevant but that they are not always discussable. Perhaps those situations in which discussion has been reduced to T topics are an indication to the developer to be particularly sensitive to O and P issues!

In summary, multiple perspectives are useful in informing ones *approach* to purposeful activity, such as the R17 project or the development of the ISDM/Q methodology. The *content* of the ISDM/Q reflects the multiple perspective approach insofar as the modules align tolerably well with the notions TOP (analysis of organization, O, socio-technical analysis and design, P, and design and construction of technical arefacts, T). This suggests that when conducting IS development one should consider the organizational, work-life and technological outcomes jointly and approach any activity through the dimensions of T, O, and P, regardless of how "technical" (e.g., database design) the activity might appear on the surface.

8.1.2 Structuration theory

In structuration theory action and structure are a co-presence, mediated by an interpretive scheme. Thus, in structurational terms the action of IS development is constrained by the structures of the organizational context, yet at the same time IS development shapes the organizational context. This seems to be an appropriate way of viewing the action research, where the author was constrained by the organizational context yet, even though it was in a small way, his actions did result in changes to the structures of signification, such as a recognition of the value of adopting a customer-focused approach to Wind Tunnel Department activity. The results of action are undeterminable, being subject to unintended consequences such that one can never be sure how a situation will play itself out. For IS developers grounded in the means-end rationality of engineering this can be a difficult proposition to accept - rather than aspire to determinism developers need to develop reflexivity, trust their tacit knowledge, and maintain a sensitivity to the situation that goes beyond a Technical worldview.

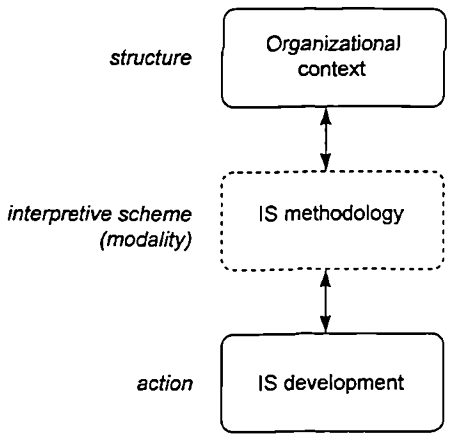


Figure 8.2: structuration theory and IS development

But that does not mean that action is random and uninformed. According to structuration theory action and structure are related through modalities: an interpretative scheme is a stock of knowledge drawn upon by human actors to make sense of their own and others' actions; a facility is the ability to allocate resources (human and material); and a norm is used to sanction actions by drawing upon standards concerning notions of "good" and "bad". With respect to IS development a formalized IS methodology may well form part of the interpretive scheme (figure 8.2), but we should also bear in mind that, according to structuration theory, an IS methodology would also be inextricably part of the domination and legitimation structures. For example a methodology might be a basis for disciplining and controlling unruly developers (power) and it could be used to justify the actions of the system development organization to the user community (sanction).

Structuration theory provides a reminder of the need to maintain an awareness of the context in which activity is being undertaken, to develop reflexivity such that the developer is sensitive to changes in the context of IS development, and to accept that we cannot know how a situation will play itself out.

8.1.3 Actor-network theory

Neither multiple perspectives nor structuration theory is specific about technology. The T perspective is concerned with technical rationality, not technical artefacts and technology per se. Orlikowski & Robey (1991) use structuration theory to view technology as both constructed by human agents and as being a constraint and enabler of human action. However, it was noted in chapter 4 that Garnsey (1990) considers Orlikowski & Robey's formulation misleading because it treats technology as a structural property - Giddens views social structures as memory traces in the mind rather than as a physical structure. In this author's opinion this is a reasonable criticism and it has influenced the view of IS development presented in figure 8.2, from which technology is notably absent. Orlikowski (1992) is also criticised by Monteiro & Hansleth (1996) for not paying enough attention to the technology when applying structuration theory to a study of CASE tool adoption. The outcome of these criticisms is: firstly in theoretical terms technology should not be viewed as a structural property; and secondly, even if technology is viewed as structure, such a conceptualization is too abstract and coarse-grained to be of practical use in describing the role of technology in IS development.

According to actor-network theory (ANT) the R17 project needs a network of allies to be successful. Some of these allies are non-human, such as UNIX work-stations, C programs, and tunnel control systems and some are human, such as operators and supervisors, programmers, and quality assurers. IS development is thus concerned with creating a lash-up of heterogeneous and disorderly allies (section 4.5.3). Latour argues that technology is society made durable and that things are the ballast of society (section 4.5.2.2). If this is so then an information system is an outcome that arises when technology has been enrolled and the actor network stabilized. This would lead us in the direction of following the various technologies through organizations and society in order that we might understand how the technologies are translated such that networks are lengthened and stabilized - i.e., the process of information system development. For example, in the Wind Tunnel Department (WTD) it might be argued that the introduction of new technologies, such as video-conferencing (section 6.2.4), might have a role to play in stabilizing the network that includes the WTD and the aerodynamicists. Although this might appear to be yet another form of technological determinism, we need only refer back to Latour's (1993) fundamental assertion that technology is more social, not less, to see that this would be a simplistic view of ANT.

ANT could, therefore, be employed to trace the network of associations between people and things that lead to a successful IS or to an IS failure. This view would depend on the extent to which technology can be a stabilizing factor in organizations. This is a notion that Pels (1995) takes exception with, arguing that:

> The notion of 'ballasting' society by things duly compensates actor-network theory's structural failure to account for the thickness and weight of reified social facts, structures and institutions.

If we accept Pels' criticism then the idea that things stabilize society should be treated with care. However, the idea of following the things that constitute an information system through the organization could provide a novel insight into how information systems develop and are developed, much as Latour & Woolgar (1979) have done with scientists. This would provide helpful learning from practice that could aid development of methodologies, methods, and techniques.

In summary, the author is cautious of placing too great a reliance on ANT and considers that this is an area for further research. One conclusion taken from ANT, which cannot be attributed to either multiple perspectives or structuration theory, is the need to keep sight of technology in all aspects of IS development. With respect to the ISDM/Q this means that:

- technology foresight is included in the analysis of organization module;
- non-human stakeholders are included in the situational analysis;
- socio-technical analysis is concerned with people, tasks, **and** technology.

8.1.4 Mediation and method in IS development

In the introduction to section 8.1 it was noted that central to the framework of ideas is the notion of IS development as mediation. Following Latour (1993) this author would argue that IS development as mediation is what we have always done, albeit clandestinely. In terms of the new constitution (section 4.5.2.2) we need to replace the clandestine proliferation of technological/organizational hybrids by their regulated and commonly-agreed-upon production. A mediatory approach to IS development requires that the organization be flexible in all aspects, from organizational analysis to software engineering, and to recognize that any requirement is contingent and all decisions temporary. QFD was proposed in chapter 5 as a way of (post-) rationalizing the IS development process and aiding in project management. However, in the author's opinion this will be insufficient by itself and needs to be supplemented by *method.*

In chapter 1 a distinction was made between methodologies and methods, whereby methodologies were defined as high level constructs that inform the choice of methods, while methods provide a systematic means of carrying out IS development. A methodology consists of an approach, which should make clear the assumptions that inform the process of IS development, and a content. In the case of the ISDM/Q, the *approach* is informed by multiple perspectives (TOP) and mediation with success being assessed in terms of customer satisfaction (quality). The *content* of the ISDM/Q is a set of techniques, which include SSM, OOA, SAST, and so on. However, a methodology is not sufficient; it can inform the process of IS development and provide a coherent framework for the techniques that will be deployed, but to carry out IS development in a non-random way requires an engagement with the problem situation and a systematic approach if the efforts of those involved are to be co-ordinated.

From experience of case study research into the implementation of SSADM Wastell (1996) comments:

> Methodology becomes a fetish, a procedure used with pathological rigidity for its own sake, not as a means to an end. Used in this way, methodology provides a relief against anxiety; it insulates the practitioner from the risks and uncertainties of real engagement with people and problems. (p. 34)

Difficulties of engagement arose during the fieldwork. The current author entered the problem situation with the aim of applying the techniques of the ISDM/Q in their entirety, regardless of what might be appropriate in this specific context and, for example, was determined to apply stakeholder analysis "according to the book" regardless of whether or not the participants saw this is as useful or meaningful. However, once the author entered into a genuine dialogue with the problem situation then engagement was achieved and progress could be made.

This suggests that IS developers need to engage with the situation and construct a situation-specific method. This method should be informed by an IS development methodology and by a project strategy that is specific to the situation. The project strategy should address aspects such as project aims, objectives, and user design structures (Eason 1992). A method such as SSADM can provide a useful template for organizing the work of IS development, but it is just that - a template that allows a development team to re-use the generalised learning and experience of others. Methods, therefore, are situation-specific devices that firstly support a genuine engagement with a problem situation, and secondly a vehicle for systematic intervention that is methodologically informed.

8.2 Learning about quality in IS development

In this section the original theme of the research, IS failure, is re-visited and the learning about quality management in IS development is recorded.

8.2.1 Success and failure in IS development revisited

The research was motivated by a concern with the high level of IS developments that are considered, in one sense or another, to be failures. The view of IS failure adopted at the start of this research was of expectation failure and multiple stakeholders (Lyytinen & Hirschheim 1987). The tradition of TQM has as a central organizing principle the idea of customer satisfaction and it was argued that adopting a quality approach to IS development would be a positive approach to understanding IS success and failure. The proposition of the research was given in chapter 1 to be:

The adoption of a quality approach to information systems development will contribute to the delivery of successful information systems

Expectation failure holds that an IS failure must pose a problem for someone or some group and is therefore situation-specific and socially constructed. In the reflections on the role of ANT in the framework of ideas above it was suggested that an IS emerges when technical artefeacts are enrolled into a network, and the longer and more irreversible the network then the more successful the IS.

To explore the idea of success and failure using ANT the author will use the R17 project as an example. The data acquisition software (DAS) has no momentum of its own and can only be successful if it is enrolled by others. For example, if the operators decide not to use the DAS, for whatever reason, then in ANT terms it is a failure. If the operators begin to use DAS prototypes and do not revert back to old systems then the network will be strengthened. Yet more allies will need to be enrolled to make the DAS more secure. For example, the software quality assurance team can translate the DAS through software inspection and the health and safety executive can translate the DAS by pronouncing it acceptable for tunnel operation. The physical DAS has not changed in the sense that it is still the same artefact, but it has changed insomuch as it has been translated through the actions of other actors. The developers of the DAS can appeal to the interests of aerodynamicists by incorporating real-time data processing and strengthen the network further. The more allies, human and non-human, that can be brought to the side of the DAS then the stronger and more irreversible the network and the more the DAS can be claimed to be a successful information system. From the supplier's perspective success therefore depends upon enrolling others so that a technical artefact, such as the DAS, becomes a black box that is disseminated over space and time; it also depends on keeping the allies in line so that what is disseminated remains broadly the same.

It seems that ANT can provide a general basis for assessing success and for defining a view of an information system as a stabilized network that results from the enrolment of technical artefacts. However, this thesis began with the notion of stakeholders and their specific expectation failures. Is there still a role for expectation failure in IS development if we adopt ANT? The author argues that although ANT might provide a basis for a general theory of success and failure it is not in itself sufficient. Vidgen & McMaster (1996) comment that motor cars and atomic bombs might be considered to be "successful" in ANT terms, but there would be considerable dissensus in terms of an expectation failure viewpoint. The difference is that not everybody gains from being enrolled into a network, for example prison inmates, and some will be excluded from the network, as highlighted by the concern about those who do not have access to technology in an information society.

If the operators in the wind tunnel refuse to use the DAS or if the software quality assurance team refuse to pass the DAS for operational use then in it is indisputably a failure - it has not gathered the necessary allies. However, this is a narrow view of success that can be broadened through the introduction of multiple perspectives. In a situation where a new piece of technology might have implications for the intensification of work, loss of job satisfaction, and even work safety implications then we can imagine that from a P perspective the abandonment of the technology might be counted a success. The difference seems to be that we are considering the interests of different actors; in one case the technology and in another the technology *user*. This issue then comes full circle to the issues of the identity of the actors and their interests, which might be amenable to a stakeholder analysis approach that caters for non-human stakeholders.

8.2.2 Quality and qualities in IS development

Notions of failure and success are helpful because they lead us to focus attention on stakeholder interests rather than IS functionality. One way of understanding and taking account of stakeholder interests is to establish the qualities that each stakeholder group expects of an IS. The principal aim of quality management is to achieve customer satisfaction. Unfortunately, customer satisfaction is concerned with the perception of individual customers and based on vague and imprecise notions such as "fun to use". The QFD approach is to establish relationships between imprecise qualities and hard product characteristics. The "total" element of TQM is expressed in QFD by the deployment of characteristics through product functions and product parts into manufacturing.

For the benefits of a quality approach to IS development to be realized it is essential that demanded qualities be given a higher profile. Qualities are the fuzzy things that reflect a stakeholder's interests and it seems reasonable to assume that they will endure over time. Unfortunately, IS developers are focused on a functional view of the world and the functions, parts, and characteristics of an IS are likely to be less durable and less stable than customer demanded qualities. The author proposes that QFD, especially when combined with a powerful means of conceptualization such as SSM, would provide a sound basis for understanding stakeholders' interests.

The conclusion reached thus far is that successful information systems should be achievable through the adoption of quality management methods. Two areas for concern arise: what are the barriers to development organizations in adopting the ideas and practices of quality management and, in situations characterized by multiple stakeholders, how are conflicts of interest to be addressed? The first issue relates to the culture of the organization and the second to the dispensation of power.

8.2.2.1 Cultural aspects of quality management: service and engineering

In chapter 4 multiple perspectives of IS quality were proposed as organizational quality, work-life quality, and technical artefact quality, which represent the content of IS quality, corresponding one to one with the ISDM/Q modules analysis of organization, socio-technical analysis and design, and design and construction of technical artefacts. As with IS development, multiple perspectives can be used to inform the approach taken to IS quality, whereby: a T approach is concerned with quality methods such as QFD; an O approach with establishing a quality culture, and a P approach with empowerment. The fieldwork demonstrated that adopting a T approach to quality is unlikely to be successful in the absence of O and P based initiatives.

The results of phase 1 of the research (interviews of system developers) together with experiences of the action research lead this author to the view that a service approach to IS development would involve a considerable change in the culture of IS development organizations and that this will be rather difficult to achieve. However, if TQM techniques, such as QFD, and principles such as customer satisfaction are to be made part of the interpretive scheme then one strategy would be to re-position the IS department as a service provider since this could provide a meaningful O and P context for customer-focused techniques such as QFD.

A service view of IS development would also provide a counterbalance to the prevailing view of IS development as engineering. Taking a service view means that developers would need to get closer to customers, to understand better how customers use information systems, and to become proficient in managing customer expectations. In chapter 2 it was noted that there is evidence of a service approach to IS development being adopted. Rands (1992), for example, has proposed a framework for IT as a service operation in which service quality is proposed as a surrogate for IT effectiveness. The traditional activities of analysis and design are still present in Rands' framework, but the prevailing metaphor is of service rather than engineering.

8.2.2.2 Critical aspects of quality management

In situations characterized by multiple stakeholders there may be conflicts between the interests of different stakeholders. QFD caters for conflict between requirements through interaction analysis in the roof of the house of quality and by the provision of specific trade-off matrices, such as cost deployment. Trade-offs in QFD take place with the assumption of consensus and agreement about ends - a critical element is conspicuously absent from the QFD literature. In section 4.4 the issues of power and a critical perspective were discussed, the debate leading to an impasse that pointed toward structuration theory and ANT, and in section 4.5.2 Latour's comment that domination is an effect rather than a cause was noted. However, this does not mean that, in ANT terms, ethical and professional values need be ignored, only that for ethical beliefs (Wood-Harper et al. 1996) to have any effect they will need to be enrolled in a network. In ANT terms, to enrol actors into an ethical network is the same task as creating an information system or establishing a fact - an appeal to their interests must be made.

8.2.3 Business process redesign and TQM

In chapter 2 business process redesign (BPR) was described and contrasted with TQM and in chapter 6 it was noted that the re-visioning of business processes is a fundamental aspect of BPR. With respect to the content and approach of the ISDM/Q it would appear that the methodology caters for both TQM and BPR approaches to IS development.

When the author joined the R17 project the scope was fairly narrow, the intention being to replace the current DAS, and the customers of the project were taken for granted as being the operators and supervisors in the wind tunnel department. By placing the project in a broader organizational context it was possible to see the strategic implications of the project and to think in terms of business improvements rather than operational efficiency gains. In the re-visioning phase of the action research (section 6.2.2.2) various possibilities for radical change were identified that involved cross-organizational change. It can be argued that these visions of radical change would have satisfied the classical notions of what constitutes BPR.

However, in the author's opinion the difference between BPR and TQM is better expressed as a boundary distinction. Drawing a wider boundary allowed us to think about the WTD and the aerodynamicists as a whole and therefore to reflect on the purpose of this larger system. While restricted to the WTD the R17 project could only redesign its working practices within a more narrow boundary with minimal affect on the working practices of the aerodynamicists. Such boundaries are artificial and often spurious and therefore the distinction between BPR and TQM is most likely to reduce to a debate concerning scope and boundary placement.

A more significant difference is the emphasis placed on processes in BPR. BPR is often legitimated through an appeal to Hammer & Champy's (1993) three

Cs - customers, competition, and change - but it has already been noted above that a process orientation is not necessarily an appropriate starting place for establishing the qualities demanded by customers. In the ISDM/Q the combination of quality requirements gathering, QFD, and SSM for reconceptualization is proposed as a synthesis of TQM and BPR ideas.

8.2.4 Learning about quality from IS development

There are lessons to be drawn for quality from IS theory and experiences of IS development. It was noted in chapter 2 that TQM lacked a coherent and well-defined set of ideas and the author suggests that the common themes of TQM can be expressed succinctly using multiple perspectives:

- T the *technical* approach involves measurement, control, management, and improvement through methods such as QFD;
- O the organizational view of quality is concerned with the establishment of a quality culture such that quality is total and not restricted to pockets of the organization;
- P the personal view of quality is concerned with individuals taking responsibility and with empowerment.

A further contribution of a multiple perspective approach is in recognizing that all three are inter-linked and inseparable and that multiple perspectives are relevant to all types of activity at multiple levels.

The ideas of multiple stakeholders and expectation failure are fundamental to quality and customer satisfaction. Unfortunately, the quality literature seems to get stuck in a T perspective and to recognize only a very narrow selection of stakeholders. Customers are often chosen on the basis of consumers/purchasers and the basis for privileging certain stakeholders over others is often left unstated or is legitimated through an appeal to the imperatives of the market. Indeed, all of the activities in the analysis of organization module of the ISDM/Q would seem an appropriate framework for analyzing any type of product or service.

8.3 Evaluation of the research

The research approach was described in chapter 3. Given the aims of the research set out in chapter 1 it seems that the research approach was appropriate since learning has been recorded at the level of the methodology (chapter 7) and the framework of ideas (chapter 8).

8.3.1 The unfolding of the research

In chapter 3 the three phases of the research were illustrated in a research framework (figure 3.9). The proposed research is reproduced in figure 8.3a together with the actual unfolding of the research as perceived by the author (figure 8.3b). The significant difference between the figures is that the level of intervention, assessed in terms of change, is significantly less than had been planned. The third phase of the research was concerned with the application of the ISDM/Q via action research.

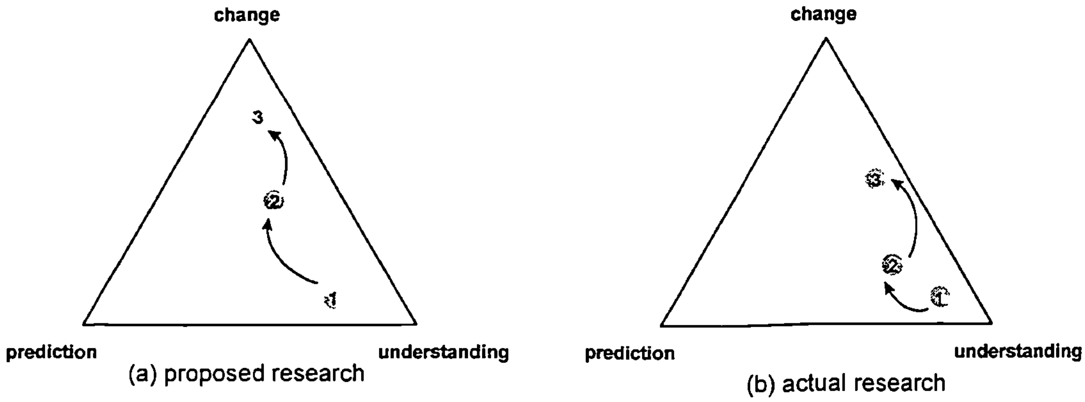


Figure 8.3: proposed and actual research

In practice the level of intervention was rather less than expected. Gaining access to part of the organization for the purposes of testing a new methodology proved to be difficult and when access was negotiated then there was no requirement for the organization to participate. Conducting action research is the same as carrying out any piece of IS development insofar as the participants must perceive the intervention as meaningful if they are to be involved and for change to come about. The lessons recorded concerning the use of multiple perspectives seem to be as relevant to action research as they are to information system development. The author needed to develop the ISDM/Q (T), gain inter-departmental co-operation (O) and build relationships with individuals who were under no obligation to provide access and resources to the researcher (P).

8.3.2 Contributions and shortcomings

A practical contribution to IS research has been made through the fieldwork, which involved extensions to the Multiview methodology and the development of IS quality function deployment (IS-QFD). The lessons from using the different techniques in the ISDM/Q have been recorded in chapter 7 and for the most part reflect practical experience that could be disseminated. The ideas and methods in the ISDM/Q have since been applied in an EU project concerned with engineering design optimization and in a commercial application for assessing IT effectiveness.

It could be argued that any success that the ISDM/Q might enjoy in practice is due to the efforts and attributes of the researcher and that the methodology might not be transferable to other developers. This argument can be levelled at any methodology. Checkland & Scholes' (1990) respond by pointing out that a claim that a methodology does not work can be countered with a rebuttal that this is due to the way it was applied, while a claim that a methodology does indeed work can be attributed to the skill of the person applying the methodology. The answer is more likely to be found in the conjunction of the developer *and* the methodology (Wood-Harper & Avison 1992).

It can also be argued that as the research was carried out in a single organization the results would not be transferable to other organizations and that there is insufficient data from which to generalize. The author would respond to this criticism that the single organization was chosen in order to get a depth of involvement (the action research lasted a year and absorbed a very significant level of effort) and richness that would not be possible from a series of more superficial case studies. However, once a method has been evolved through action research it is important that it be subjected to different situations and applied by different people if its usefulness is to be evaluated. This work is beyond the scope of this research and should form part of a programme of future work.

In terms of the contributions to IS theory, a number of outcomes have been recorded in chapter 7 with respect to the use of the methodology and its constituent methods. Learning with respect to the framework recorded in this chapter includes:

- the role of multiple perspectives in informing the approach to IS development as well as the content of a methodology;
- IS methodologies as interpretive schemes that require situation-specific methods in the interests of engagement and co-ordination;
- the need to keep technology present at all stages of an IS development;
- the idea of an IS as a stabilized network of technical artefacts;
- a re-interpretation of the notion of IS success and failure through actor-network theory;
- the adoption of a service view of IS development organizations in order to address cultural aspects of quality management;
- a broader conception of quality and a stronger set of ideas that are relevant outside of the IS domain.

8.3.3 Future work

Areas for future work include:

- further development and practical application of IS-QFD as a delivery mechanism for TQM in IS development;
- theoretical and practical development of the systems-based methods SSM, SAST for the incorporation of non-human stakeholders;
- the application of actor-network theory for empirical study of IS development;
- further development of the framework of ideas and the implications of combining ideas from structuration theory, actor-network theory and multiple perspectives.

The researcher is confident that organizations that adopt the ISDM/Q approach to IS development will be able to improve the likelihood of delivering successful information systems, but only as part of a wider programme that accounts for cultural issues.

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Glossary

acronym	description
ADABAS	A mainframe database management system
ARA	Aerospace Research Association
BCAPE	BAe Computer Aided Production Electrical
BCAWD	BAe Computer Aided Wiring Design
CAE	Computer-aided Engineering
CAM	Computer-aided Manufacturing
CASE	Computer-aided Software Engineering
CIM	Computer-integrated Manufacturing
CMM	Capability Maturity Model - used to assess software process capability (see SPICE)
CSC	Computer Sciences Corporation - the provider of IT services to BAe
CSP	Control Sequence Program - used in the wind tunnel to control a wind tunnel run
DAS	Data Acquisition System
DFD	Data Flow Diagram (used in structured methods such as SSADM)
DRA	Defence Research Agency
EFA	European Fighter Aircraft
GUI	Graphical User Interface (e.g., Windows)
HCI	Human Computer Interaction
HSWT	High Speed Wind Tunnel
IS	Information System

acronym	description
ISO	International Standards Organization
IT	Information Technology
JET	Jet Environment Testing
LED	A semiconductor diode that converts applied voltage to light and is used in digital displays, as of a calculator (light-emitting diode)
LSWT	Low Speed Wind Tunnel
O	The Organizational perspective
OMT	Object Modelling Technique
OO	Object-Orientation
P	The Personal perspective
QFD	Quality Function Deployment
R17	Internal BAe project code for the DAS project
SEI	Software Engineering Institute - developer of the CMM
SPICE	Software Process Improvement and Capability Determination - an international response to the CMM developed by the SEI
SSADM	Structured Systems Analysis and Design Method
SSM	Soft Systems Methodology, developed by Peter Checkland at Lancaster University
T	The Technical perspective
TRIPOS	A BAe application running on an ADABAS database for storing aerodynamic data
UNIX	an open operating system used run on work-stations such as Sun
VDU	Visual Display Unit
WTD	Wind Tunnel Department

Appendices

A

Background to the wind tunnel department

A.1 Wind Tunnel Department organization and facilities

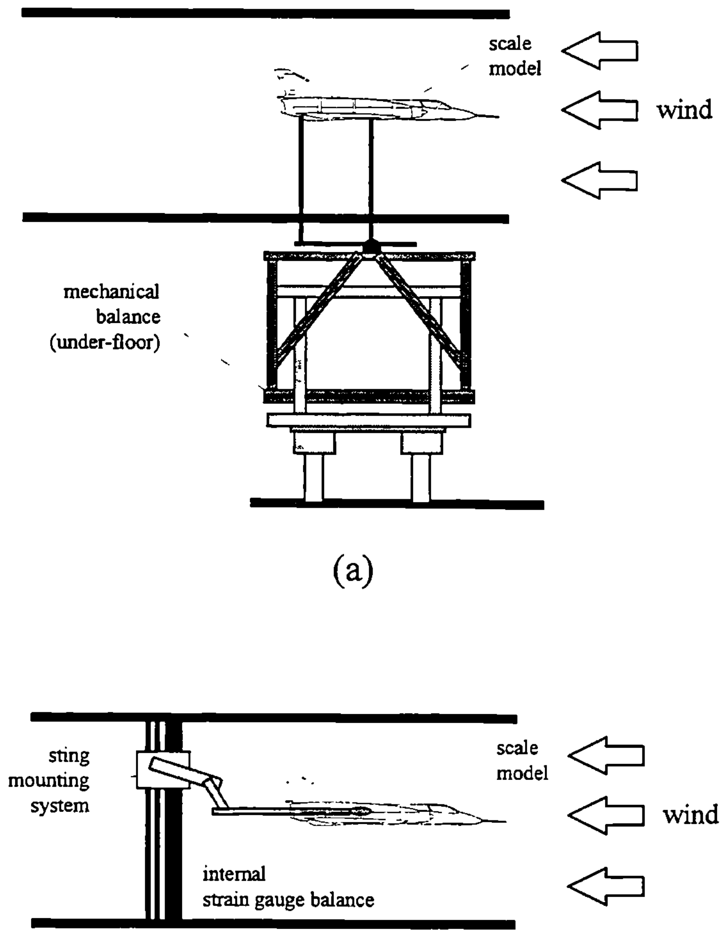
The Wind Tunnel Department (WTD) is part of Aerodynamic Technology within the Technical Directorate of BAe Military Aircraft. The WTD operates and manages a number of test facilities:

- Low Speed Testing
  - 2.7m Low Speed Wind Tunnel (LSWT)
  - 4.0m LSWT
  - 5.5m LSWT
- High Speed Testing
  - 1.2 m High Speed Wind Tunnel (HSWT)
- Jet Environment Testing (JET)
  - Hot Gas Laboratory
  - Advanced Gas Facility
- Design & Manufacture
  - Design of models
  - Model Shop (wood)
  - Model Shop (metal)

This research is concerned with the operation of high speed and low speed wind tunnels and only indirectly with JET and Design & Manufacture (this latter group constructs models for use in wind tunnels). The 2.7m LSWT is scheduled for closure, once the 4.0m LSWT is in full production. The above facilities are all at the Warton site, on which wind tunnel facilities are being concentrated. There are also some basic test facilities at Brough.

A.2 Wind Tunnel operation

With respect to LSWTs, the 4.0m tunnel is a good example of wind tunnel technology. The 4.0m tunnel is a continuous flow tunnel with a speed range of 5 to 105 m/s supplied by a fan. In the simplest terms, a model is placed on a sting in a tunnel and the wind turned on (figure A.1b). The sting mounting system traverses the model through a pre-defined range of incidences (known as alpha) and sideslips (beta). The combination of incidence and sideslip is known as the model attitude. In general, one factor is designated as the test variable, such as incidence, and all the other variables, such as sideslip, tunnel speed, and model configuration are held constant for the duration of the run. A common test is to move the model through a range of incidences while keeping the other variables constant - this type of test is known as an 'incidence traverse'.



(a)

(b)

Figure A.1: low speed wind tunnel - model, sting, and balances

The forces and moments on the model can be measured using transducers in one of two ways:

- by the under-floor mechanical balance. Forces and moments are transmitted through the movements of the struts in the balance (figure A.1a);
- by a strain gauge balance located inside the model (figure A.1b).

To compensate for the weight of the model a tare traverse is taken with the wind turned off - this set of values is then subtracted from the readings obtained when the wind is on. Tare values are typically taken at coarser incidence intervals than the wind-on data as the tare values are a smooth function and can be interpolated. Wind tunnel test data is collected using a Data Acquisition System (DAS). The DAS collects analogue data through a number of channels by scanning. The analogue data is sampled and converted into digital form and presented in engineering units - this is known as *raw data*. Corrections are applied to compensate for the artificial aspects of the wind tunnel (scaling, tunnel characteristics, etc.) resulting in *processed data*. It is this processed data that is the best approximation of the aerodynamic characteristics of the full-size target object.

The high speed wind tunnel (HSWT) operates on the same principles, but has some significant differences. For example, the HSWT has a different sting mechanism and has no under-floor mechanical balance - force and moment data is collected using an internal strain gauge. The HSWT is a blow-down tunnel; air is pressurized in long cylindrical containers and released through the tunnel, which is effectively a long tube opening into the atmosphere. Consequently, there is no continuous air circulation in a blow-down HSWT. The duration of a HSWT test is typically 45 seconds and, because of the short duration, the model is traversed rapidly through a predetermined sequence of test attitudes automatically. One of the drawbacks of the HSWT is the time it takes to re-pressurize the air containers, which can result in long elapsed times in completing a series of test runs. By contrast, the low speed tunnels can run continuously and can accommodate test runs of any duration. The Aerospace Research Association (ARA) at Bedford has a continuous flow HSWT which Aerodynamic Technology make use of as an alternative to the BAe HSWT facility. A continuous HSWT would involve significant investment and it is unlikely that BAe will build their own facility.

A.3 Wind Tunnel customers

The principal customers for the WTD are the aerodynamicists working in Aerodynamic Technology, who are located in three main sites: Warton, Brough, and Farnborough. Aerodynamicists require data to help them solve aerodynamic problems in response to operational requirements, ranging from new aircraft designs to minor modifications, such as the positioning of a store pylon (items such as missiles and external fuel tanks are known as 'stores'). WTD and aerodynamic personnel often need to work together closely and in many cases aerodynamicists wish to be present while a test run is being conducted, especially in situations where a new design is being tested and there is uncertainty about the outcome. As wind tunnel facilities continue to be concentrated on the Warton site there are increasing geographical difficulties for Brough and Farnborough.

The wind tunnel department has a small amount of external work, including wind tunnel tests of motor cars and sea-craft. This work tends to be ad hoc and is not currently a significant source of revenue.

A.4 Wind Tunnel Strategy

The presence of a wind tunnel facility at Warton has the benefit of guaranteed and controlled access to test facilities and is considered to be a strategic requirement by BAe senior management. The stated policy of the WTD in terms of business objectives are (report BAE-WWT-PL-GEN-DEP-940462 - Operational Plan):

- continually strive to improve effectiveness;
- adopt new test techniques and equipment when expedient;
- continually improve quality;
- optimize the balance between Military Aircraft and external customer requirements;
- operate all facilities within Health, Safety and the Environment legislation.

A general theme of the WTD is to promote flexible working and to re-organize around functions rather than operating each of the tunnels as mini wind tunnel departments. Figure A.2 shows planned changes to the organization structure. WTD management consider that a common DAS design and common wind tunnel control systems, particularly in the area of user interfaces for wind tunnel operation, are needed to support a flexible, facility-based approach to WTD activity. This proposed change represents a more general movement within BAe toward customer-facing organization rather than one organized around the supplier's view of a department's operations. However, this is a major change in working practice and is expected to have a significant impact on the nature of organizational work in the

WTD.

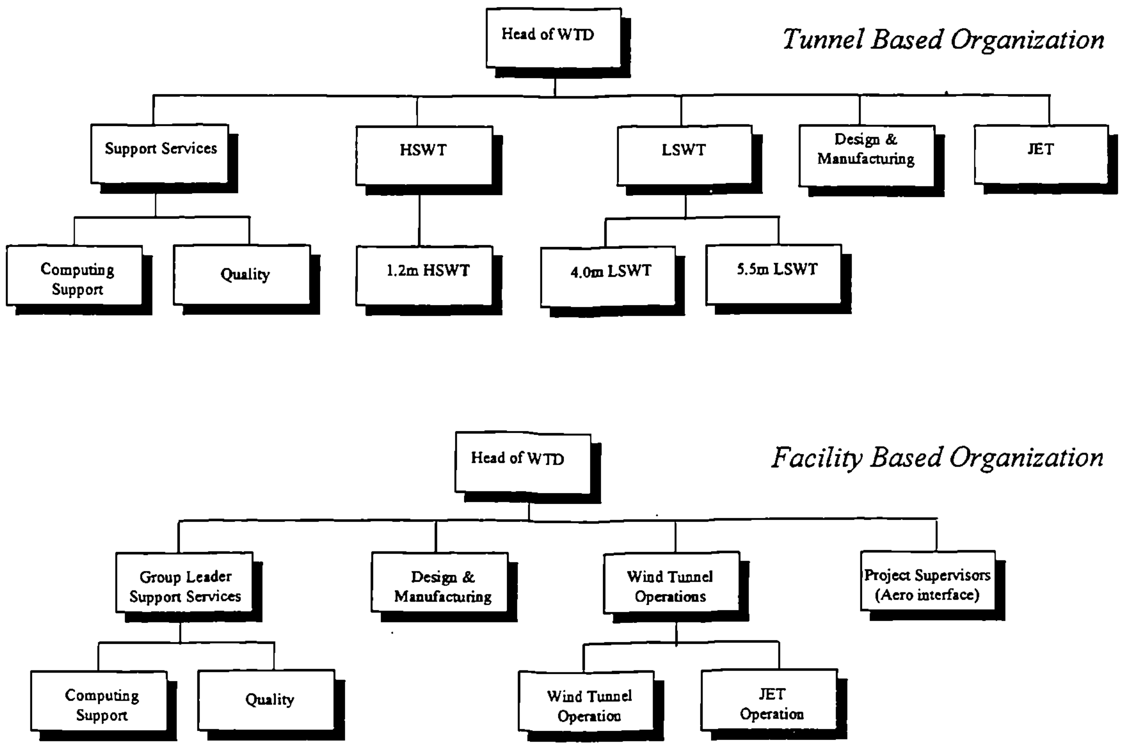


Figure A.2: proposed WTD re-organization

A.5 Current computing environment

The current computing environment has two distinct components (figure A.3). The DAS is work-station based and is concerned with collecting analogue signals, sampling, and conversion into engineering units. For example, data could be collected at 1 kHz for 3 seconds, resulting in 3000 readings for each of, say, ten parameters (lift, drag, incidence, etc.) - a grand total of 30,000 data items. Using mathematical processes these 30,000 items will be reduced to 10 readings (one per data channel), which are then converted into engineering units using calibration factors. The original, sampled signal data is held in memory on the work-station until the reduction is complete; it is not needed after the run has finished and is therefore not retained. The raw data then needs to be processed to produce aerodynamic data that can be used by the customer. Data processing takes place on the mainframe, the results being finally stored and indexed on a mainframe ADABAS database called TRIPOS. At this point the data is of use to aerodynamicists.

There is a delay associated with the transfer of data from the work-station to the mainframe and the submission of batch mainframe processing. The mainframe is an effective repository of wind tunnel test run data, but it is not suited to real-time processing of data at the point of collection.

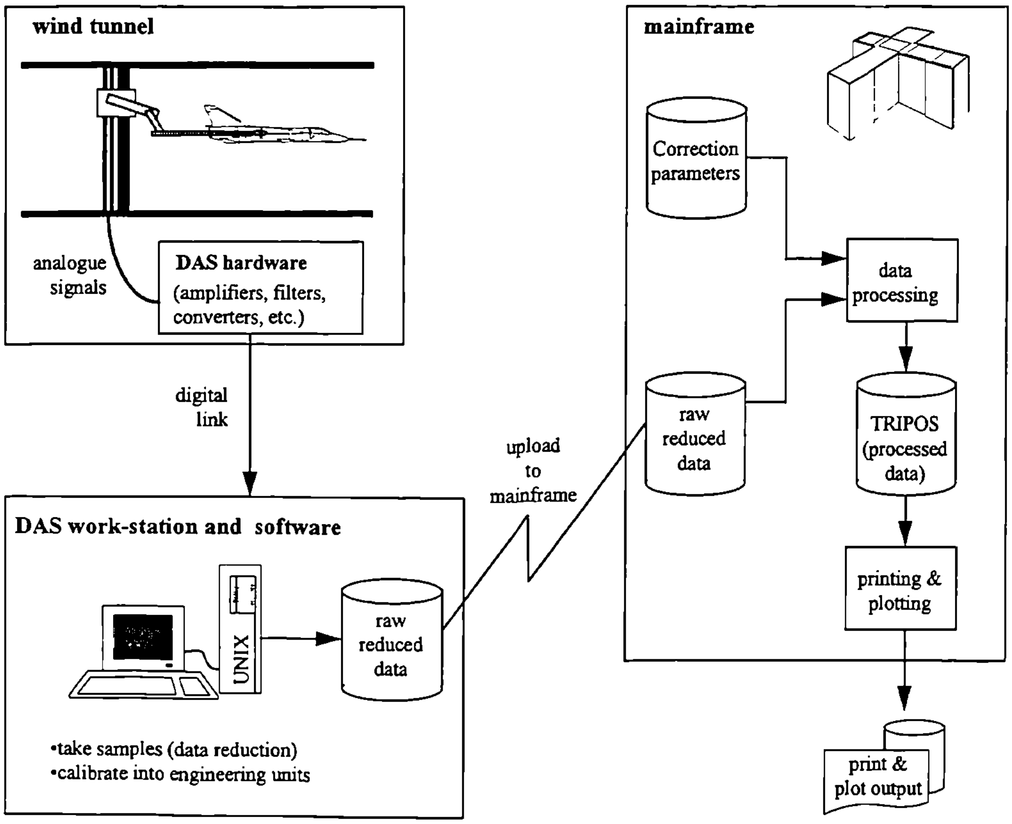


Figure A.3: LSWT - current computing environment and data-flow

Computer system development - organization

The DAS/R17 project is being developed by Technical Computing, which reports through CAE & Technical to the Technical Directorate of BAe. Although development of the TRIPOS database on the mainframe is also the responsibility of Technical Computing, the operation of the mainframe has been out-sourced to the US-based Computer Sciences Corporation (CSC). The scope of the out-sourcing includes IT development that is for administration and management reporting purposes. It does not include core aerospace applications, such as flight control systems and the wind tunnel control system. In practice it is quite difficult to draw the line between support and core IT; the Technical Computing group has some systems that fall into a grey area between the two and at one time there was a possibility that Technical Computing would be out-sourced - as of the current date this has not happened. The presence of out-sourcing has contributed toward uncertainty amongst BAe development staff and has added an extra layer of complexity to project development for Technical Computing. For example, CSC are responsible for maintaining UNIX work-stations and therefore Technical Computing need to negotiate a service level agreement with CSC.

A.6 Tunnel operation software and DAS - Project R17

In 1988 a proposal was made to replace the HSWT data acquisition system (DAS) to give more channels, higher sampling rates, and improved reliability over the ageing current system, which is expensive to maintain. The cost was then estimated at £450k. The proposal was rejected and subsequently re-submitted each year until a proposal to replace both the 4.0m LSWT and the 1.2m HSWT DASs was accepted, at a cost of £262k for both tunnels. This will give a greatly improved data acquisition facility and will provide the potential for real-time processing of WT data. PROSIG, the supplier of the new data acquisition hardware and Sun/UNIX software interface, is scheduled to complete a staged delivery by early 1996. Concurrently with the upgrading of the data acquisition hardware, new wind tunnel control software is being developed. The current mode of low-speed tunnel operation is labour-intensive and requires manual integration of the various WT components, such as sting movement, DAS interfacing, and tunnel speed control (high-speed tunnel operation is of necessity automated due to the short run duration). The current high level of manual intervention means that considerable experience of wind tunnel operation is needed and operator errors are more likely to occur. Tunnel throughput has suffered accordingly.

The project to develop new tunnel operation software is known as R17. Prototype software is being developed using a graphical user interface (GUI) allowing the operator to establish a control sequence program (CSP) that will move the model support through the required incidences and acquire data automatically. Although the prototype software is communicating with the old DAS, it is being developed such that the new DAS can be plugged in with minimal software modifications. Major functional requirements identified for the R17 software include:

- provide a GUI based system that provides a consistent method between tunnels;
- acquisition and recording of tunnel and model data;
- provision of run facilities such as archive, graphics, tables, audit trail;
- interfacing to external systems and equipment for control and monitoring purposes (e.g., mechanical balance, calibration equipment, fan drive);
- continuous monitoring of signals for alarm purposes;
- real-time display of signal values in various forms, such as dials, bar graphs, and tabular;
- development and execution of control sequence programs (CSPs) with testing in simulation mode;
- ability to do multiple testing (e.g., set up and check out the next job while the current test run is executing);
- amplifier and transducer calibration;
- data reduction by averaging, RMS, digital filtering, etc.

The software is being developed by Technical Computing using the C programming language and a user interface builder on a Sun/UNIX platform. The development work is being carried out currently by a single developer under the guidance of a project manager (extra technical resource is planned to be allocated to the project at the beginning of 1996). The head of Technical Computing is taking a management interest in the R17 project and all three Technical Computing representatives attend the monthly R17 Project Board meetings.

B

Quality requirements workshops

Information System Quality

Wind Tunnels Requirements Workshop for Aerodynamics

Agenda

10.00	Introduction: Wind Tunnel improvement programme update (WTD representative)
10.10	Information Systems Quality project overview (Richard Vidgen)
10.20	Review of the current situation (all)
11.00	Quality requirements gathering (all)
12.15	Quality requirements grouping (all)
12.45	Conclusion (Richard Vidgen/WTD representative)
13.00	Finish

Wind Tunnels Requirements Workshop for Aerodynamics - briefing document

Likely attendees

- Farnborough Aerodynamicists (including Aero management)
- Wind Tunnel Department representative
- Software Quality Assurance representative (project sponsors)
- Richard Vidgen (University of Salford)

Wind Tunnel update

The WTD representative will give a brief update on progress at the Wind Tunnel in upgrading facilities and provide a context for today's workshop.

Information Systems Quality

A brief introduction by Richard Vidgen to outline:

- background to the IS quality project
- aims of the requirements workshop
    - to understand Aero requirements of Wind Tunnels, leading to
        - agreement on quality factors
        - agreement on importance weighting of quality factors
        - agreement on assessment of quality factors
- agenda for the day

Current situation

Aim: to create a shared understanding of the context in which Aero and Wind Tunnels are working; to surface issues, stakeholders.

Quality requirements gathering

This is a technique for gathering the "voice of the customer". We begin with a fairly general phrase:

"what do Aero customers require and expect from the Wind Tunnels department?"

We will attempt to surface:

- customer requirements
- current issues (problems)
- opportunities
- BAe strategic factors
- constraints

Ideas will be collected using post*It* notes. One idea per post*It*; concisely expressed; written clearly and in large letters; retaining the actual words of the customer as far as possible. On the back of the post*It* we will attempt to record *why* the requirement is important. The provider of the demanded quality will be encouraged to write the quality on the post*It* using their own words.

Aim: to create a list of qualities demanded by Aero of Wind Tunnels.

Quality requirements grouping

The post*It*s will be spread out randomly on the conference room table. The group will then work in silence, grouping post*It*s that seem to be related. The aim is to group all post*It*s into at most 10 groups; single post*It*s should not be forced into a group - loners are OK. Once the grouping is completed, one post*It* in each group should be selected that reflects the meaning of the group - if there is no suitable post*It* then a new one is written.

Aim: to create a grouped set of demanded qualities based upon the affinities between requirements as perceived by Aero.

Conclusion

Summarize the findings of the workshop.

Get immediate feedback from workshop attendees using the attached questionnaire.

What happens next? Richard Vidgen will assemble the post*It*s into an affinity diagram, together with Warton and Farnborough requirements.

These quality requirements will then need to be weighted for importance by Aero personnel. There probably will not be time to do this during the workshop. We plan to put all the Aero requirements into questionnaire form and circulate it to Aero personnel, asking them to rank the relative importance of the requirements on a 1 to 10 scale.

Once we have gathered and understood the customer requirements of Wind Tunnels we shall turn our focus into the Wind Tunnel operations, where we will be asking questions such as: how well do Wind Tunnel meet customer requirements (this involves identifying measures of quality that are meaningful to Aero)? How might software, such as DAS, be deployed to help Wind Tunnel better meet customer needs?

Notes

1. Coffee break(s) as appropriate. Ideally, coffee facilities available in room and people stop as they feel like - no set break for coffee where all activity stops.
2. Facilities required:
    - Flip chart
    - Large conference table - this will used as a work board for the post*It*s
    - Seating arrangement - informal. Attendees should be able to get up and walk around the table while we are gathering and grouping requirements

Richard Vidgen
June 1995

Wind Tunnel Requirements Workshop for Aerodynamics
Evaluation Questionnaire

Attendee name:	Department:

	strongly disagree						strongly agree
1 The workshop fulfilled the stated aims and objectives	☐	☐	☐	☐	☐	☐	☐
3 The affinity diagramming technique brought out the requirements that Aero have of WInd Tunnels	☐	☐	☐	☐	☐	☐	☐
4 The affinity diagramming technique brought out related isuues	☐	☐	☐	☐	☐	☐	☐
5 Following the workshop I feel that Wind Tunnels understand better the needs of their customers	☐	☐	☐	☐	☐	☐	☐
6 I am confident that Wind Tunnels department will take action on the basis of their customer's needs	☐	☐	☐	☐	☐	☐	☐
7 The workshop format was an effective medium for expressing customer requirements	☐	☐	☐	☐	☐	☐	☐
8 The facilitation of the workshop struck a good balance between structure and free-form discussion	☐	☐	☐	☐	☐	☐	☐

Comments:

	no	yes
Would you be willing to participate in a follow-up workshop (possibly involving personnel from other sites)	☐	☐

C

Demanded qualities

Warton Aero Personnel

Verbatim requirements gathered at workshop held 12 April 1995

Additional facilities/hardware

ReqID	PostIt text	Justification (on back of PostIt)
A1	Need Tripos on work stations	mainframe is under strain. Ease of using work station - quicker interfaces
A2a	Require additional facilities - vertical spin tunnel	currently have to go elsewhere - ARA, Lille
A2b	Require additional facilities - ability to capture yaw rate derivatives	currently have to go elsewhere - ARA, Lille
A3	Store balance and ma n balance, and pressure tapping simultaneously	will save on cost and run times
A4	Extension of attainable valid data range - incidence, side slip, mach no., Reynolds no.	have to interpolate or go elsewhere, e.g., ARA
A5	Enhancements to rotary rigs	

Teamworking

ReqID	PostIt text	Justification (on back of PostIt)
B1	Improvement in interface with design office drawings	
B2	Wind Tunnel test specified completely and run as specified	
B3	Handle unplanned choices in Wind Tunnel test immediately	
B4	Minimize Aero staff time wasted in wind tunnel during test	
B5	Tests run as specified and how to verify	
B6	How is the run specification configured	
B7	Model validation	
B8	Aerodynamicist present during wind tunnel runs - Farnborough, Brough	
B9	Short test programme duration	
B10	Wind Tunnel test queries resolved in real-time	

Visualization/presentation of Wind Tunnel results

ReqID	PostIt text	Justification (on back of PostIt)
C1	Improved flow visualization	Additional information
C2	See data in quick plots in derivative and coefficient form	Currently have to wait for data to be fully QA'd before can do it
C3	Verfication of test conditions and configuration	Data quality
C4	Video visualization of wind tunnel test	
C5	Wind tunnel data animation	Picture of a wing and animation of the flow - important for presenting data to Aero customers
C6	Graphical representation and storage	Visualization of data: static

Data format

ReqID	PostIt text	Justification (on back of PostIt)
D1	Wind tunnel data in a standard format	Data from different tunnels in different format - can be different from same wind tunnel. Format inclludes naming conventions, sign convention, units, structure
D2	All data in computer-networked form	Sometimes get magnetic tape; wind tunnel DAS cannot cope with high acquisition rate and mass storage
D3	Part or fully processed data available from wind tunnel	Timeliness of data - otherwise non-value added steps
D4	Wind tunnel corrected data available real-time with wind tunnel test	Takes a week to get corrections applied - sometimes get it the next day
D5	Access to raw wind tunnel data	Raw data is uncorrected data - not milli-volts but unprocessed detail data. Useful to answer questions about corrections, e.g., to compare other facilities such as EFA partners, ARA
D6	Pre-QA'd data available ASAP in Aerodynamics	Currently need to travel over to wind tunnel for each run to see this data

Availability

ReqID	PostIt text	Justification (on back of PostIt)
E1	Wind tunnel test slots available on demand	
E2	Only one HSWT - bottleneck	
E3	HSWT air shared with weapons testing	
E4	High sampling rate	20k /sec minimum on each of 50 channels for 10 secs - to compensate for scaling effects and adequate frequency range

Quality/accuracy

ReqID	PostIt text	Justification (on back of PostIt)
F1	Data repeatability	
F2	Data is free of error	data OK for repeatability tests. Wasted effort in Aero
F3	Ensure maximum data accuracy	
F4	Data integrity checks from drawings	
F5	Verification of corrections to data	Data integrity. Assures correct data
F6	Data accuracy/tolerances. Currently Aero do not know what they can have	

Brough Aero Personnel

Verbatim requirements gathered at workshop held 22 June

ReqID	PostIt text
R100	Surface finish on model; look after model surfaces post test
R101	Require ease of access to data both at (online) and post Wind Tunnel test
R102	(Wind Tunnels) need a desire to prove new technologies to capture new business. Improve image!
R103	Access to online data at remote site during test
R104	No funding to validate new models/facilities! i.e., KA3, KA1 in 4m
R105	Use of video links on work stations to brief staff at other sites
R106	Common plotting in Aero and across wind tunnels
R107	Repeatability between test sites, i.e., look after the model
R108	Data status on TRIPOS (preliminary or final)
R109	Data presentation to include all corrections, test conditions, etc.
R110	Provision of reports!
R111	Need for more aerodynamics knowhow by WT staff to ensure validity of methods and data
R112	Require instant visibility of data from calibration rigs
R113	A statement on overall results accuracy?
R114	WTs to emphasize validation of new techniques/hardware BEFORE testing
R115	Representative models and flows (to full scale).
R116	Maintain models so that representative models and flows can be achieved consistently throughout the model/tunnel life
R117	Timely REPORTS defining tests undertaken and the basis or standard of the results (e.g., corrections applied, data reduction details)
R118	INTERIM statement can be given to satisfy more immediate requirements for giving flight clearances
R119	Rapid data access/retrieval to mainframe storage facility
R120	Realtime data acquisition available at home base (e.g., force/moment characteristics displayed graphically with overlay facility with previously generated data)
R121	Rapid turnaround (from requirements to final data) to meet project timescales

Farnborough Aero Personnel

Verbatim requirements gathered at workshop held 6 July 1995

Group	Group	Req ID	PostIt text	Comment and justification
Data quality		F100	Consistent data format	
		F101	Good repeatability of data	
		F102	Audit trail for data reduction	
		F103	Automatic processing of data - no manual intervention	
		F104	Machine-readable data	main form of data delivery
		F105	Eye-readable data	
Administration	Scheduling	F106	Rapid delivery of estimates	Reasonable delivery time depends upon complexity of estimate. Different attendees had different ideas of reasonable: week to a month OR 2 days to a week. Feeling is that this is very variable at present
		F107	Flexible test scheduling	
		F108	Short time between request and test result	affected by model design, model build, and model calibration
	Planning & Reporting	F109	Post-test reports on time, agreed content, circulated to Aero	
		F110	Easy budget reporting - spend/achievement and time/achievement	are we coming in on budget? Need to know during the test series
		F111	In-test progress reports (weekly)	this is Technical achievement
		F112	Guidelines for best practice re forming test programmes, etc.	should help to reduce the time taken to get an agreed test plan
Cost		F113	Minimmum overall cost	fewer rig operators, avoid design frills, avoid tea-breaks
Data Communications		F114	Easy access to processed data	
		F115	Rapid data communications	online is ideal; off-line same day next best; three months wait is worst
		F116	Virtual attendance	video and data links. Minimize wasted time.
		F117	Efficient dedicated data viewing/plotting system for customer	remote access preferable
		F118	Accessible electronic run-list (& transportable)	produced by project supervisor; Aero want to see this pre and post run. Currently it is bits of paper and faxes (want planned and actual)
Staff communications		F119	Contact names and numbers - overall organization	organization plan - who fits where and does what
		F120	Contact names and numbers - you job	who is working on it?
		F121	Encourage use of email systems	
		F122	Answerphones, all-in-one, or call-logging at WTs	
Tunnelling capability		F123	Continuous data acquisition during model motion (continuous pitch vs pitch-pause)	Would lead to higher throughput and therefore lower cost. Note: not possible in 4m LSWT
Staff skills/service		F124	High level of staff expertise (WT aerodynamicists?) - recruitment and training	Kingston had no rig operators - they had trained engineers who happened to operate rigs
		F125	Consciencious (careful) trained operators	rig operation & aero principles
		F126	Don't be too proud to ask for help	
		F127	Admit to errors	
Model Management		F128	Model inventory	
		F129	Low-cost models	should consider sub-contract
		F130	Acceptable accuracy of models	agreed between WT & Aero

Verbatim issues gathered at workshop held 6 July 1995 with Farnborough Aero personnel

Group	Group	Req ID	PostIt text	Comment and justification
Data communications and personal		G100	Data access is very difficult	no decent link to TRIPOS - this is a Warton system; can't use it even when they do get in
		G101	Electronic comms are very difficult	speed of links - 5minutes to get a screenful of data (Network busy?)
		G102	Commincation difficulties due to remoteness	Warton do not use All-in-one (half and half - some do, CE just starting)
		G103	Never answer the phone	
		G104	No instant visibility of data (data links)	
Timescale		G105	Long time to produce data to Aero (months)	Processed data
		G106	Testing flexibility	scheduling issue - if run out of time, somebody else will be in there, so have to come back later
		G107	Long time to sort (recognize?) problems	
Operational procedures		G108	Lack of guidelines for programming	series of WT test runs - no guidelines, have to rely on WT project supervisor. E.g., no. of runs needed for repeatability (Aero would like guidelines)
Computing facilities		G109	Limited/inadequate on-line plotting	
		G110	Not enough disk space	MASCOMP
WT internal communications		G111	WT staff absence	
		G112	WT staff do not talk to each other	
		G113	Change of staff	
Staff Expertise	Aero principles	G114	Operators don't understand principles of fluid dynamics	rig operators don't know when they have done something wrong
		G115	Lack of appropriate expertise	
	Operational problems	G116	Operators don't understand the DAS system	
		G117	Wrong gains on t-c channels	
		G118	Operator mistakes	Ground effects rigs
		G119	WT staff did not know when software was correct or not (Aero had to check/test)	Ground Effect Rig - only knew data was a problem when customer told them

Demanded Qualities - Version DQ2

1st level	2nd level		3rd level	verbatim source
Operations	Test series	1	can schedule test series to meet project timescales	R121
		2	can supply accurate test series estimate quickly	F106
		3	is flexible in scheduling test series	F107
		4	can provide guidance in establishing test series plan	F112
		5	agrees complete test series specifications	B2
		6	minimizes time spent in the tunnel	F103, F123, F108, A3, B9, E1, E2, E3
	Test run	7	minimizes the amount of unnecessary Aero involvement on test run	R103, R120, F116, C4, B4, B8
		8	responds quickly to exception situations in a standard test run	B3, B10
		9	executes test run as specified	B2, B5
Service	Staff	10	has staff who are conscientious and open	F125, F126, F127
		11	has staff with a good knowledge of aerodynamics	F124, R111
	Communication	12	keeps customer informed of status of test series	R117, F110, F111, F118
		13	keeps customer informed of status of test run	R117, F110, F111, F118
		14	has clear lines of communication between customer and WT	R105, F119, F120
		15	responds quickly to customer contacts	F121, F122
Cost	Cost	16	will minimize cost of test series	F113, F129
Facilities	WT facilities	17	has tunnels with representative flows	R115
		18	has wide range of tunnel parameters	A4
	Technology	19	will thoroughly test any new WT-related technology	R114
		20	has a variety of modern WT facilities	A2a, A2b, R104, R102, A5
Data	Data quality	21	has high level of repeatability	R107, F101, F1
		22	supplies accurate data	F3, F6, R113, F130, E4
		23	supplies error-free data	F2
		24	supplies data in a known state	R109, R117, F102, F5, R112, R108, B6, C3, D5
	Delivery	25	supplies data on a timely basis	R118, R119, R120, F115, C2, D3, D4, D6, F109
		26	makes data available in a known format	F100, D1
		27	makes data available in appropriate medium	F104, F105, C1, R110, C6, C5, F117
		28	makes data easily accessible	R101, F114, A1
		29	uses IT consistently	D2, R106
	Use	30	promotes reuse of historic test run data	General issue arising from requirements workshops
Models	Models	31	uses representative models	R115, B7, F4, F130, B1
		32	looks after models	R100, F128, R107, R116

Information System Quality Project

Quality Dictionary

Qualities of Wind Tunnel Department demanded by Aerodynamic Technology

September 1995

Richard Vidgen (University of Salford) and the

Wind Tunnel Department (BAe)

Quality requirement no: 1

Quality requirement title: *can schedule test series to meet project timescales*

Source: R121

Quality requirement description:

Most of the work in Aerodynamic Technology is organized by project, such as Tornado and EFA. Scheduling of test series into the a wind tunnel should reflect the relative project priorities.

Justification:

Alignment with BAe business priorities.

Comments:

Each test series could be given a priority that reflects the project urgency. The priority could be set by Aero in consultation with the Chief Engineers.

Quality requirement no: 2

Quality requirement title: *can supply accurate test series estimate quickly*

Source: F106

Quality requirement description:

When Aero have a requirement for a test series they want to know:

- when can the test series be started
- how long will it take
- how much will it cost

Justification:

Aero need this information in order to prepare estimates of time and cost for the projects.

Comments:

Estimates might need to be matched to the complexity of the test series. For example, simple estimates might have a target turnaround of 3 working days and complex estimates a target of 6 working days. It would also be necessary to have an acceptance period, following which the estimate expires if it has not been committed to by Aero.

Quality requirement no: 3

Quality requirement title: *is flexible in scheduling test series*

Source: F107

Quality requirement description:

The WT department must be able to respond to urgent test run requests.

Justification:

BAe maintain a WT facility to give it an independence from third party WT facilities. Part of this is the ability to run a test at any time (subject to competing project priorities).

Comments:

Test series requests should be prioritized - a special case procedure is needed for urgent test runs. If this option is abused then the scheduling of standard test series will be affected and customer satisfaction will suffer (the prioritization mechanism must also be perceived to be fair).

Quality requirement no:	4
Quality requirement title:	*can provide guidance in establishing test series plan*
Source:	F112

Quality requirement description:

WT staff have specific and detailed knowledge that can be used to help Aerodynamicists in preparing a list of test requirements.

Justification:

A good test plan needs Aero and WT input.

Comments:

Cross-fertilization of WT and Aero knowledge will help. Aero need to understand capabilities and limitations of WT technology and WT need to understand how Aero use WT test results.

Quality requirement no:	5
Quality requirement title:	*agrees complete test series specifications*
Source:	B2

Quality requirement description:

The test series specification should contain complete and unambiguous details of the test series, including: test runs, model and tunnel configurations.

Justification:

WT operators should not have to interpret or guess what is required in a test run.

Comments:

It is important that WT and Aero agree all details and that if unresolved items are later found then they should be agreed between WT and Aero rather than guessed by WT.

Quality requirement no:	6
Quality requirement title:	*minimizes time spent in the tunnel*
Source:	F103, F123, F108, A3, B9, E1, E2, E3

Quality requirement description:

A test series should be completed as quickly as possible. This requirement refers to the time elapsed from starting the test to finishing the test and delivering the processed test data.

Justification:

The quicker that data is available the quicker Aero can meet the requirements of the projects.

The longer time needed in the tunnels, the higher the cost.

Comments:

This requirement has significant implications. If a test series is scheduled but not completed in the allocated time then further tunnel time will need to be booked - since other tests will be scheduled into the tunnel there may be a delay in getting back into the tunnel and therefore a significant delay to Aero. Once in the tunnel throughput needs to be improved - this can be achieved in many different ways (e.g., reduce operator error; abort test runs that are in error, use continuous data acquisition, collect all data in a single traverse, etc.).

Quality requirement no:	7
Quality requirement title:	*minimizes the amount of unnecessary Aero involvement on test run*
Source:	R103, R120, F116, C4, B4, B8

Quality requirement description:

Aero staff do not want to spend unproductive time travelling or sitting in a tunnel watching a standard test run. However, for ad hoc runs and development work it is often essential that Aero are present to observe the progress of the run as it unfolds in real-time.

Justification:

Make best use of Aero staff time.

Comments:

Travel time can be reduced by supplying fully processed test run data in real-time to remote sites; test runs could be categorized as:

standard - no attendance required

ad hoc - attendance preferred (this could be virtual attendance from a remote site or physical attendance in the tunnel).

Quality requirement no:	8
Quality requirement title:	*responds quickly to exception situations in a standard test run*
Source:	B3, B10

Quality requirement description:

Aero want the facility to make ad hoc and fast decisions when something unusual occurs during a standard test run, which the WT test supervisor needs to make Aero aware of - there is no point in continuing a test run (or series of test runs) if the supervisor suspects that the data is either invalid or not useful.

Justification:

Reduce time spent in tunnel and ensure that Aero get useful data.

Comments:

WT operators and Aero personnel will need fast availability of processed data to make timely decisions - this requires that processed data is made available in real-time. Aero need not be physically present at the test but will need remote access to processed test data.

WT staff will need to be customer-facing and responsive (proactive, not reactive).

Quality requirement no: 9

Quality requirement title: *executes test run as specified*

Source: B2, B5

Quality requirement description:

The test run is executed precisely as specified in the test run plan.

Justification:

Conformance to specification.

Comments:

How can Aero be sure that the test run was executed as specified. This may require that photographs, video records are maintained in order that items such as model configuration can be verified.

Quality requirement no: 10

Quality requirement title: *has staff who are conscientious and open*

Source: F125, F126, F127

Quality requirement description:

Aero want to deal with WT staff who take them seriously, who care about their work, who can admit to making mistakes, and are not too proud to ask questions! This seems to indicate the need for a more open style of working between Aero and WT.

Justification:

This is a basic requirement of a customer-oriented organization.

Comments:

The cultures of the Aero and WT departments are quite different and the difficulty of achieving this requirement should not be underestimated.

Quality requirement no: 11

Quality requirement title: *has staff with a good knowledge of aerodynamics*

Source: F124, R111

Quality requirement description:

WT staff creating the test series specification and operating WTs should have a good grounding in aerodynamic principles.

Justification:

WT supervisors and operators will be able to recognize when a test series is adequate, when a test run has a problem, and whether the data produced is reasonable.

Comments:

Will help to improve communications between WT and Aero and to bridge the cultural divide.

Quality requirement no:	12
Quality requirement title:	*keeps customer informed of status of test series*
Source:	R117, F110, F111, F118

Quality requirement description:

Aero want to be able to see the status of a test series at any point from the submission of an estimate. The status should include achievement against time, achievement against spend, and any other indicators of progress that will help to ascertain success of the series. They also wish to be able to see a run-list of the test runs that comprise a test series.

Justification:

Keeping the customer informed of progress (even when there is very little) is essential to good customer relations.

Comments:

Typically, this process currently involves Aero telephoning WT to find out progress. WT should consider:

- sending progress reports to Aero on a pro-active and regular basis (e.g., weekly)
- making the progress data available using IT (e.g., Groupware such as Lotus Notes) - Aero could find out the status of their test series without waiting to the end of the week or for WT to call them back. This would involve a more open working style, where the status of each run is immediately made available after a run. It could replace a lot of manual paperwork and possibly remove the need for an end of test series report.

Quality requirement no:	13
Quality requirement title:	*keeps customer informed of status of test run*
Source:	R117, F110, F111, F118

Quality requirement description:

This is similar to requirement 12, but relates to an individual run and is concerned with keeping Aero informed of progress while a particular test run is being executed.

Justification:

If Aero are aware of progress while the run is taking place they will have the opportunity to propose alternative courses of action, such as aborting a test run and saving tunnel time.

Comments:

This requirement would require real-time processed data to be available at the tunnel and remotely.

Quality requirement no: 14

Quality requirement title: *has clear lines of communication between customer and WT*

Source: R105, F119, F120

Quality requirement description:

Aero wish to know the general organization structure of WT and the specific organization of a particular test series and each test run.

Justification:

Difficulties arise where Aero do not know who is responsible for their test series, Good communication will be enhanced by clear lines of responsibility.

Comments:

IT can be used to make this information available on a network, avoiding the need to update users of changes.

Quality requirement no: 15

Quality requirement title: *responds quickly to customer contacts*

Source: F121, F122

Quality requirement description:

Aero want WT to respond quickly to contacts.

Justification:

Basic element of customer service.

Comments:

Problems arise when the required person from WT is unavailable to answer the telephone. This might involve a commitment to call back within 10 minutes if no one is available to answer the telephone. Alternatives to the telephone need to be considered, such as faxes, but particularly electronic forms, such as email.

Quality requirement no: 16

Quality requirement title: *will minimize cost of test series*

Source: F113, F129

Quality requirement description:

Cost is related to tunnel time and man hours effort and to low-cost models.

Justification:

Save time on WT tests and help Aero to get project work completed more quickly.

Comments:

This requirement relates to tunnel throughput, model construction, and the deployment of new technologies (for example, pressure-sensitive paint should allow an existing model to be used to get a pressure contour much more cheaply than building in tubes and transducers into the model).

Quality requirement no: 17

Quality requirement title: *has tunnels with representative flows*

Source: R115

Quality requirement description:

The flow in the tunnel should result in data that is as free as possible from distortions and biases that arise from the design, construction, and maintenance of the tunnel.

Justification:

The flow will be more realistic and easier to compare to flight test data and to other tunnels' data.

Comments:

The tunnels need to be calibrated throughout the working section to understand the flow uniformity. Maintenance is also important since, for example, a clogged screen can affect tunnel flow

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Quality requirement no: 18

Quality requirement title: *has wide range of tunnel parameters*

Source: A4

Quality requirement description:

Relates to factors such as model attitude range, tunnel speed, Renolds numbers. Also these ranges should not have gaps in them, such as a tunnel speed range that has speeds within the range that are unavailable.

Justification:

Flexibility of tunnel parameters will give a wider range of aerodynamic data and minimize the need to external facilities.

Comments:

Quality requirement no: 19

Quality requirement title: *will thoroughly test any new WT-related technology*

Source: R114

Quality requirement description:

Aero want to feel confident that any new WT facilities and associated hardware and software have been fully tested.

Justification:

Time and reputation are wasted through delivering faulty data.

Comments:

Quality requirement no:	20
Quality requirement title:	*has a variety of modern WT facilities*
Source:	A2a, A2b, R104, R102, A5

Quality requirement description:

Aero want WT department to supply advanced facilities such as vertical spin testing, continuous flow HSWT.

Justification:

More sophisticated tests are requested by projects.

Comments:

Aero can go outside for these facilities. WT might consider operating an advisory service and then subcontracting the work as appropriate.

Quality requirement no:	21
Quality requirement title:	*has high level of repeatability*
Source:	R107, F101, F1

Quality requirement description:

Repeatability gives confidence that the data is acceptable.

Justification:

If the same data can be produced at different times using the same model in the same tunnel then Aero will feel comfortable that the configuration and the tunnel set-up are consistent. This also relates to the repeatability of using the same model in different tunnels (e.g., ARA).

Comments:

This does not guarantee that the data is accurate, only that it is consistent.

Quality requirement no:	22
Quality requirement title:	*supplies accurate data*
Source:	F3, F6, R113, F130, E4

Quality requirement description:

The data reflects the aerodynamic characteristics of the object faithfully.

Justification:

Accurate data is essential to Aero.

Comments:

Difficult to ascertain - how accurate need it be? The acid test is a comparison to flight test data, but this is difficult. Data can also be compared to other tunnels (e.g., ARA) that are generally believed to provide quality data.

WTD do not currently specify the accuracy of the data that they supply.

Quality requirement no:	23
Quality requirement title:	*supplies error-free data*
Source:	F2

Quality requirement description:

The data can be affected by errors arising from multiple sources, including:

- operator-error
- incorrect model configuration
- an unidentified fault occurring during the test run
- data processing
  - wrong modules executed
  - modules executed in incorrect sequence

Justification:

The data should be error-free.

Comments:

Quality requirement no:	24
Quality requirement title:	*supplies data in a known state*
Source:	R109, R117, F102, F5, R112, R108, B6, C3, D5

Quality requirement description:

Aero need to know:

- model configuration
- tunnel configuration
- corrections applied to the data in processing (audit trail is required)

This requirement relates to the reconstructability of a test run - either immediately following the test run or at some time in the future.

Justification:

The context in which the data is produced needs to be known if the data is to be used and reused with confidence.

Comments:

This is a data management issue.

Quality requirement no:	25
Quality requirement title:	*supplies data on a timely basis*
Source:	R118, R119, R120, F115, C2, D3, D4, D6, F109

Quality requirement description:

Aero want fully processed data as soon as possible, ideally produced in real-time with the test run. Where it is a LSWT standard run or a HSWT run then they can wait until the run is complete, but want the fully processed data available from a central repository as quickly as possible.

Justification:

The more quickly fully processed data can be supplied then the more quickly action can be taken to optimize the execution of a test series.

Comments:

Control over data is needed, especially if it is to be made available a test run and immediately after the completion of the test run. It is proposed that three levels of data quality be used on TRIPOS:

- *provisional* data (category A) - data is released immediately the run is complete. This processed data is unchecked by WT supervisor;
- *checked* data (category B) - data that has been checked by WT supervisor;
- *approved* data (category C) - data that has been approved by Aero as being acceptable.

Records of who has accessed the data will need to be kept as some data will not make it to category C status.

Quality requirement no:	26
Quality requirement title:	*makes data available in a known format*
Source:	F100, D1

Quality requirement description:

Aero want a consistent data format for all WT data. This relates to the format of the files used to input and output data from TRIPOS and also to the units of measurement - for example Renolds number might be per metre or per foot.

Justification:

Common routines can be used to process data in Aero; no ambiguity about what the data is.

Comments:

Data from external facilities may be in different formats (can be reformatted into TRIPOS standard) and may use different units. Conversion routines can be used locally to move TRIPOS data to local platforms. This means that the TRIPOS interface should be fully documented and, as far as possible, unvarying.

Quality requirement no:	27
Quality requirement title:	*makes data available in appropriate medium*
Source:	F104, F105, C1, R110, C6, C5, F117

Quality requirement description:

Aero want the test data and other reports in a media that are compatible with their IT environment and supported by the following formats:

- machine readable
- eye-readable (numbers, test, graphics)
- visual (flow)
- video
- animation

Justification:

Data is used in a different ways to solve different aerodynamic problems.

Comments:

Quality requirement no: 28

Quality requirement title: *makes data easily accessible*

Source: R101, F114, A1

Quality requirement description:

Aero want to be able to get at the data quickly and easily.

Justification:

Comments:

This might involve moving TRIPOS from the mainframe to a work-station environment.

Quality requirement no: 29

Quality requirement title: *uses IT consistently*

Source: D2, R106

Quality requirement description:

Aero don't want to be changing from workstation to mainframe to PC to complete a single logical task.

Justification:

Comments:

Data display facilities at the tunnel should be the same as the aerodynamicist's place of work so that they are familiar with the system in the tunnel and can also use the system remotely without having to learn/switch systems.

Quality requirement no: 30

Quality requirement title: *promotes reuse of historic test run data*

Source: general issue arising from requirements workshops

Quality requirement description:

Aero wish to add to a database of test run data and where possible to reuse existing data rather than re-run the same test (or something very similar) in the WT.

Justification:

It is quicker and cheaper to reuse data than to recreate it in a WT test.

Comments:

Finding similar previous test runs can be difficult; implies need for a shared database of test run data, possibly including non-BAe WTs and even CFD data. Searching can be difficult and might need more than SQL, e.g., Case-Based Reasoning facilities for fuzzy matching.

Quality requirement no: 31

Quality requirement title: *uses representative models*

Source: R115, B7, F4, F130, B1

Quality requirement description:

The model should reflect the object being modelled faithfully.

Justification:

A basic requirement.

Comments:

The model should be within agreed tolerances of the drawing that it represents.

Quality requirement no: 32

Quality requirement title: *looks after models*

Source: R100, F128, R107, R116

Quality requirement description:

Model surfaces are maintained and models boxed and stored carefully with all parts properly labelled and compartmentalized.

Justification:

If models are damaged or assembled using incorrect fixings or parts then the data will be less useful and repeatability will suffer.

Comments:

D

Demanded qualities analysis

Wind Tunnels: qualities demanded by Aerodynamic Technology

				Importance to Aerodynamics (least important … most important)	WT Dept. performance (very unsatisfactory, unsatisfactory, adequate, good, excellent)	competitor performance (very unsatisfactory, unsatisfactory, adequate, good, excellent)
Operations	Test series	1	can schedule test series to meet project timescales	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		2	can supply accurate test series estimate quickly	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		3	is flexible in scheduling test series	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		4	can provide guidance in establishing test series plan	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		5	agrees complete test series specifications	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		6	minimizes time spent in the tunnel	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
	Test run	7	minimizes the amount of unnecessary Aero involvement on test run	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		8	responds quickly to exception situations in a standard test run	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		9	executes test run as specified	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
Service	Staff	10	has staff who are conscientious and open	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		11	has staff with a good knowledge of aerodynamics	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
	Communication	12	keeps customer informed of status of test series	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		13	keeps customer informed of status of test run	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		14	has clear lines of communication between customer and WT	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		15	responds quickly to customer contacts	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
Cost	Cost	16	will minimize cost of test series	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
Facilities	WT facilities	17	has tunnels with representative flows	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		18	has wide range of tunnel parameters	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
	Technology	19	will thoroughly test any new WT-related technology	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		20	has a variety of modern WT facilities	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
Data	Data quality	21	has high level of repeatability	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		22	supplies accurate data	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		23	supplies error-free data	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		24	supplies data in a known state	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
	Delivery	25	supplies data on a timely basis	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		26	makes data available in a known format	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		27	makes data available in appropriate medium	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		28	makes data easily accessible	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		29	uses IT consistently	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
	Use	30	promotes reuse of historic test run data	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
Models	Models	31	uses representative models	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5
		32	looks after models	1 2 3 4 5 6 7 8 9	1 2 3 4 5	1 2 3 4 5

Name & Job Title*

Location

* not esential, but please complete location (e.g., Brough, Farnborough, Warton)

WTD Competitor(s)

Date

Please supply any additional comments on a separate sheet. Thank you for completing this questionnaire.

Demanded qualities

	Warton respondent 1	Warton respondent 2	Warton respondent 3	Warton respondent 4	Warton respondent 5	Warton respondent 6	Warton respondent 7	Warton respondent 8	Warton average	Farnboro respondent 1	Farnboro respondent 2	Farnboro respondent 3	Farnboro respondent 4	Farnboro respondent 5	Farnboro respondent 6	Farnboro respondent 7	Farnboro average	Brough respondent 1	Brough respondent 2	Brough respondent 3	Brough average	Overall average
Service																						
1 can schedule test series to meet project timescales	9	8	5	6	9	8	3	9	7.1	8	9	7	6	7	9	8	7.7	9	8	9	8.7	7.6
2 can supply accurate test series estimate quickly	8	7		1	5	5	3	6	5.0	7	6	5	2	6	4	9	5.6	6	3	5	4.7	5.2
3 is flexible in scheduling test series	5	8	3	1	5	7	3	7	4.9	6	7	8	5	5	8	7	6.6	8	7	7	7.3	5.9
4 can provide guidance in establishing test series plan	6	7	7	1	7	6	3	3	5.0	7	6	7	1	5	2	4	4.6	8	7	4	6.3	5.1
5 agrees complete test series specifications	7	6	8	6	5	7	3		6.0	4	6	5	7		6	3	5.2	4	4	5	4.3	5.4
6 minimizes time spent in the tunnel	8	6	5	4	3	8	3	8	5.6	4	5	2	4	4	5	8	4.6	7	6	7	6.7	5.4
7 minimizes the amount of unnecessary Aero involvement on test run	6	7	7	1	7	8	4	6	5.8	6	5	6	3	6	1	2	4.1	6	4	5	5.0	5.0
8 responds quickly to exception situations in a standard test run	8	8	7	1	7	8	4	7	6.3	7	8	8	8	7	7	6	7.3	7	8	9	8.0	6.9
9 executes test run as specified	8	9	8	6	9	8	4	8	7.5	9	8	4	9	7	6	5	6.9	8	8	9	8.3	7.4
10 has staff who are conscientious and open	8	8	9	4	9	8	5	8	7.4	8	7	7	8	8	9	6	7.6	7	8	9	8.0	7.6
11 has staff with a good knowledge of aerodynamics	6	7	5	1	8	5	5	7	5.5	8	8	8	6	7	4	5	6.6	6	6	6	6.0	6.0
12 keeps customer informed of status of test series	7	7	7	6	8	9	7	7	7.3	7	8	7	5	7	8	9	7.3	8	8	7	7.7	7.3
13 keeps customer informed of status of test run	6	7	7	6	4	9	7	6	6.5	3	8	3	4	7	3	2	4.3	4	7	8	6.3	5.6
14 has clear lines of communication between customer and WT	8	8	8	4	6	9	7	6	7.0	5	9	8	9	8	5	8	7.4	7	6	8	7.0	7.2
15 responds quickly to customer contacts	8	8	9	1	8	8	7	7	7.0	6	8	8	7	8	7	7	7.3	7	8	9	8.0	7.3
16 will minimize cost of test series	9	8	7	4	8	7	8	9	7.5	7	8	5	7	5	7	9	6.9	8	6	9	7.7	7.3
17 has tunnels with representative flows	8	9	7	7	8	9	6	9	7.9	8	9	8	9	7	5	7	7.6	8	8	9	8.3	7.8
18 has wide range of tunnel parameters	8	9	7	1	8	7	6	9	6.9	9	9	7	5	7	8	4	7.0	8	7	9	8.0	7.1
19 *will thoroughly test any new WT-related* technology	6	6	7	2	9	7	1	3	5.1	6	8		5	6	6	6	6.2	8	8	6	7.3	5.9
20 has a variety of modern WT facilities	7	8	7	2	8	7	1	3	5.4	6	9	7	3	6	7	5	6.1	5	8	7	6.7	5.9
31 uses representative models	7	9	9	7	9	7	2	9	7.4	8	9	8	7	8	7	7	7.7	9	8	9	8.7	7.7
32 looks after models	6	9	5	4	7	8	2	5	5.8	8	9		4	7	4	8	6.7	9	8	9	8.7	6.6
Product																						
21 has high level of repeatability	8	9	8	9	9	9	9	9	8.8	8	8	9	5	7	6	7	7.1	8	8	9	8.3	8.1
22 supplies accurate data	9	9	8	4	9	8	9	9	8.1	8	9	9	5	8	7	8	7.7	9	8	9	8.7	8.1
23 supplies error-free data	9	9	8	9	9	8	9	9	8.8	9	9	8	9	9	4	8	8.0	7	9	9	8.3	8.4
24 supplies data in a known state	9	9	9	9	8	9	9	9	8.9	9	9	9	8	6	8	6	7.9	8	9	9	8.7	8.4
25 supplies data on a timely basis	8	9	7	4	9	8	9	9	7.9	7	8	7	7	7	9	5	7.1	8	6	7	7.0	7.4
26 makes data available in a known format	8	9	9	9	9	9	9	8	8.8	9	9	9	8	8	9	9	8.7	8	6	8	7.3	8.5
27 makes data available in appropriate medium	8	9	9	1	8	8	9	8	7.5	9	9	7	4	6	7	4	6.6	6	8	8	7.3	7.1
28 makes data easily accessible	8	9	9	2	9	8	9	7	7.6	9	9	8	6	7	9	3	7.3	5	8	7	6.7	7.3
29 uses IT consistently	5	5	9	1	9	6	9	3	5.9	8	7	7	3	5	5	2	5.3	5	8	6	6.3	5.7
30 promotes reuse of historic test run data	4	5	9	8	6	8	6	5	6.4	5	5	7	2		2	1	3.7	4	8	7	6.3	5.4

WT performance

	Warton respondent 1	Warton respondent 2	Warton respondent 3	Warton respondent 4	Warton respondent 5	Warton respondent 6	Warton respondent 7	Warton respondent 8	Warton average	Farnboro respondent 1	Farnboro respondent 2	Farnboro respondent 3	Farnboro respondent 4	Farnboro respondent 5	Farnboro respondent 6	Farnboro respondent 7	Farnboro average	Brough respondent 1	Brough respondent 2	Brough respondent 3	**Brough average**	Overall average
Service																						
1 can schedule test series to meet project timescales	4	4	1	3	1	4	3	2	2.8	3	4	3	3	3	4	4	3.4	4	3	4	3.7	3.2
2 can supply accurate test series estimate quickly	4	3		3	3	3	3		3.2	5	3	3	3	2	3	4	3.3	4	4	4	4.0	3.4
3 is flexible in scheduling test series	4	4	2	4	4	3	3		3.4	3	3	4	3	3	4	4	3.4	4	3	4	3.7	3.5
4 can provide guidance in establishing test series plan	4	4	3	4	3	3	3		3.4	2	4	4	3	3	3	4	3.3	3	4	4	3.7	3.4
5 agrees complete test *series specifications*	4	3	2	3	2	4	3		3.0	4	3	3	3		3	4	3.3	4	4	4	4.0	3.3
6 minimizes time spent in the tunnel	3	3	2	2	3	4	3		2.9	4	3	2	3		3	3	3.0	3	3	4	3.3	3.0
7 minimizes the amount of unnecessary Aero involvement on test run	4	4	2	3	3	4	2		3.1	2	3	3	3		4	4	3.2	3	4	3	3.3	3.2
8 responds quickly to exception situations in a standard test run	4	4	3	4	4	4	3		3.7	3	4	2	3		3	4	3.2	4	4	4	4.0	3.6
9 executes test run as specified	4	4	3	3	3	4	4		3.6	4	3	4	2		4	4	3.5	4	4	4	4.0	3.6
10 has staff who are conscientious and open	5	4	3	4	4	4	4		4.0	5	3	4	4	4	4	5	4.1	5	4	5	4.7	4.2
11 has staff with a good knowledge of aerodynamics	4	3	3	3	3	3	4		3.3		3	2	2	3	4	4	3.0	3	4	5	4.0	3.3
12 keeps customer informed of status of test series	3	3	4	3	4	4	4		3.6	2	4	4	3	3	3	3	3.1	4	4	5	4.3	3.5
13 keeps customer informed of status of test run	3	3	3	3	4	3	3		3.1	3	3	3	3	3	4	4	3.3	2	4	4	3.3	3.2
14 has clear lines of communication between customer and WT	4	4	4	3	2	3	4		3.4	4	3	4	2	2	4	3	3.1	3	4	4	3.7	3.4
15 responds quickly to customer contacts	5	3	3	3	4	3	3		3.4	4	4	5		2	2	3	3.3	4	4	4	4.0	3.5
16 will minimize cost of test series	3	4	2	3	3	4	3		3.1	3	4	3	3		3	3	3.2	3	4	4	3.7	3.3
17 has tunnels with representative flows	5	4	3	3	3	3	3		3.4		3	4	3	4	4	4	3.7	3	4	4	3.7	3.6
18 has wide range of tunnel parameters	5	3	4	2	3	3	2	2	3.0		3	4	3	3	3	3	3.2	4		4	4.0	3.2
19 will thoroughly test any new WT-related technology	4	4	3	3	3	3	2		3.1		4		4	3	4	3	3.6	4		3	3.5	3.4
20 has a variety of modern WT facilities	4	3	2	3	3	3	2		2.9		3	4	3	3	3	3	3.2	3		4	3.5	3.1
31 uses representative models	4	4	4	3	4	4	3		3.7	4	4	4	3	4	3	3	3.6	5	3	5	4.3	3.8
32 looks after models	3	4	2	3	5	5	4		3.7	3	4		3	3	3	3	3.2	4	4	5	4.3	3.6
Product																						
21 has high level of repeatability	3	3	2	2	3	4	3		2.9	4	4	3	3	3	4	4	3.6	3	3	4	3.3	3.2
22 supplies accurate data	4	3	3	3	2	3	3		3.0	3	4	3	3	3	3	4	3.3	4	3	4	3.7	3.2
23 supplies error-free data	4	4	2	2	3	3	4		3.1	4	4	3	2	2	3	4	3.1	4	4	4	4.0	3.3
24 supplies data in a known state	4	4	2	3	4	5	4		3.7	5	3	3	2	4	4	4	3.6	4	4	4	4.0	3.7
25 supplies data on a timely basis	4	3	2	4	1	4	4		3.1	4	4	4	2	3	2	4	3.3	3		4	3.5	3.3
26 makes data available in a known format	4	4	3	4	2	5	3		3.6	5	4	5	3	4	4	3	4.0	3	4	4	3.7	3.8
27 makes data available in appropriate medium	4	4	3	4	2	5	2		3.4	3	3	5	4	4	3	3	3.6	3	3	5	3.7	3.5
28 makes data easily accessible	4	4	3	3	2	4	2		3.1	3	3	5	4	2	2	2	3.0	3	4	5	4.0	3.2
29 uses IT consistently	3		3	3	2	3	2		2.7		2	4	2	3	3	3	2.8	4	4	4	4.0	3.0
30 promotes reuse of historic test run data	2	3	2	2	1	4	1		2.1		2	4	3		2	2	2.6	3	4	4	3.7	2.6

Competitor performance - ARA

No.	Item	respondent 1	respondent 2	respondent 3	respondent 4	respondent 5	respondent 6	respondent 7	respondent 8	Warton average	respondent 1	respondent 2	respondent 3	respondent 4	respondent 5	respondent 6	respondent 7	Famboro average	respondent 1	respondent 2	respondent 3	**Brough average**	Overall average
Service																							
1	can schedule test series to meet project timescales		3		3	4	3	3	3	3.2		2				3	4	3.0	4	3	4	3.7	3.3
2	can supply accurate test series estimate quickly		3		3	3	3	3	3	3.0		4				4	3	3.7	4	4	5	4.3	3.5
3	is flexible in scheduling test series		2		3	3	3	3	4	3.0		4				3	3	3.3	3	3	4	3.3	3.2
4	can provide guidance in establishing test series plan		4		3	2	3	3	3	3.0		4				3	4	3.7	4	4	4	4.0	3.4
5	agrees complete test series specifications		4	4	3	3	3	3		3.3		4				3	4	3.7	3	4	3	3.3	3.4
6	minimizes time spent in the tunnel		4	4	3	5	4	3	4	3.9		5				4	4	4.3	4	5	3	4.0	4.0
7	minimizes the amount of unnecessary Aero involvement on test run		4		3	3	5	2	3	3.3		4				4	4	4.0	5	4	5	4.7	3.8
8	responds quickly to exception situations in a standard test run		3		3	2	4	3	4	3.2		4				4	5	4.3	4	4	3	3.7	3.6
9	executes test run as specified		4		3	5	4	4	5	4.2		3				4	4	3.7	4	4	3	3.7	3.9
10	has staff who are conscientious and open		3	3	4	4	4	4	4	3.7		4				4	4	4.0	4	4	3	3.7	3.8
11	has staff with a good knowledge of aerodynamics		4		4	3	4	4	4	3.8		5				4	5	4.7	3	4	4	3.7	4.0
12	keeps customer informed of status of test series		3		3	3	4	3	4	3.3		4				4	4	4.0	4	4	2	3.3	3.5
13	keeps customer informed of status of test run		3		3	3	3	3	4	3.2		4				4	4	4.0	3	4	1	2.7	3.3
14	has clear lines of communication between customer and WT		4	3	3	4	3	3	4	3.4		4				4	4	4.0	4	4	2	3.3	3.5
15	responds quickly to customer contacts		4	2	3	3	3	3	5	3.3		4				4	5	4.3	4	4	4	4.0	3.7
16	will minimize cost of test series		2		3	4	4	3	3	3.2		4				4	4	4.0	4	4	3	3.7	3.5
17	has tunnels with representative flows		4		3	3	4	3	3	3.3		3				5	4	4.0	4	4	4	4.0	3.7
18	has wide range of tunnel parameters		4		3	4	3	3	4	3.5		3				4	5	4.0	4		4	4.0	3.7
19	will thoroughly test any new WT-related technology		3		3	4	3	2		3.0		4				3	5	4.0	3		5	4.0	3.5
20	has a variety of modern WT facilities		3		3	4	4	2		3.2		3				2	4	3.0	3		5	4.0	3.3
31	*uses representative models*		4		3	4	4	3	4	3.7		4				4	4	4.0	3	4	5	4.0	3.8
32	looks after models		4		3	4	5	4	4	4.0		4				3	4	3.7	3	4	5	4.0	3.9
Product																							
21	has high level of repeatability		3		2	3	4	3	3	3.0		4				4	4	4.0	3		4	3.5	3.4
22	supplies accurate data		3		3	4	5	3	3	3.5		4				4	4	4.0	4	3	5	4.0	3.8
23	supplies error-free data		4		2	4	4	4	3	3.5		4				3	3	3.3	4	4	5	4.3	3.7
24	supplies data in a known state		4		2	4	5	4	4	3.8		4				4	4	4.0	4	4	3	3.7	3.8
25	supplies data on a timely basis		4	2	3	4	5	4	4	3.7		4				4	5	4.3	3		2	2.5	3.7
26	makes data available in a known format		4	4	3	4	5	3	4	3.9		3				4	4	3.7	3	4	4	3.7	3.8
27	makes data available in appropriate medium		3	4	3	4	5	2	5	3.7		3				4	4	3.7	3	4	5	4.0	3.8
28	makes data easily accessible		4		4	4	3	2	3	3.3		3				4	4	3.7	3	3	5	3.7	3.5
29	uses IT consistently				3	3	3	2		2.8		3				3	4	3.3	4	4	4	4.0	3.3
30	promotes reuse of historic test run data		3		2	2	4	1	4	2.7		2				3	3	2.7	3	4	3	3.3	2.8

Competitor performance - DRA

	respondent 1	respondent 2	respondent 3	respondent 4	respondent 5	respondent 6	respondent 7	respondent 8	Warton average	respondent 1	respondent 2	respondent 3	respondent 4	respondent 5	respondent 6	respondent 7	Farnboro average	respondent 1	respondent 2	respondent 3	**Brough average**	Overall average
Service																						
1 can schedule test series to meet project timescales				3	4		3		3.3						3	3	3.0	4	3		3.5	3.3
2 can supply accurate test series estimate quickly				3	3		3		3.0						3	3	3.0	4	4		4.0	3.3
3 is flexible in scheduling test series				3	3		3		3.0						3	2	2.5	3	3		3.0	2.9
4 can provide guidance in establishing test series plan				3	2		3		2.7						3	4	3.5	4	4		4.0	3.3
5 agrees complete test series specifications				3	3		3		3.0						3	4	3.5	3	4		3.5	3.3
6 minimizes time spent in the tunnel				3	5		3		3.7						3	2	2.5	4	5		4.5	3.6
7 minimizes the amount of unnecessary Aero involvement on test run				3	3		2		2.7						4	3	3.5	5	4		4.5	3.4
8 responds quickly to exception situations in a standard test run				3	2		3		2.7						4	3	3.5	4	4		4.0	3.3
9 executes test run as specified				3	5		4		4.0						4	3	3.5	4	4		4.0	3.9
10 has staff who are conscientious and open				4	4		4		4.0						4	4	4.0	4	4		4.0	4.0
11 has staff with a good knowledge of aerodynamics				4	3		4		3.7						5	5	5.0	3	4		3.5	4.0
12 keeps customer informed of status of test series				3	3		3		3.0						3	2	2.5	4	4		4.0	3.1
13 keeps customer informed of status of test run				3	3		3		3.0						4	3	3.5	3	4		3.5	3.3
14 has clear lines of communication between customer and WT				3	4		3		3.3						4	3	3.5	4	4		4.0	3.6
15 responds quickly to customer contacts				3	3		3		3.0						3	3	3.0	4	4		4.0	3.3
16 will minimize cost of test series				3	4		3		3.3						3	2	2.5	4	4		4.0	3.3
17 has tunnels with representative flows				3	3		3		3.0						5	4	4.5	4	4		4.0	3.7
18 has wide range of tunnel parameters				3	4		3		3.3						5	4	4.5	4			4.0	3.8
19 will thoroughly test any new WT-related technology				3	4		2		3.0						4	3	3.5	3			3.0	3.2
20 has a variety of modern WT facilities				3	4		2		3.0						5	5	5.0	3			3.0	3.7
31 uses representative models				3	4		3		3.3						4	4	4.0	3	4		3.5	3.6
32 looks after models				3	4		4		3.7						3	4	3.5	3	4		3.5	3.6
Product																						
21 has high level of repeatability				2	3		3		2.7						4	4	4.0	3			3.0	3.2
22 supplies accurate data				3	4		3		3.3						4	4	4.0	4	3		3.5	3.6
23 supplies error-free data				2	4		4		3.3						4	3	3.5	4	4		4.0	3.6
24 supplies data in a known state				2	4		4		3.3						4	4	4.0	4	4		4.0	3.7
25 supplies data on a timely basis				3	4		4		3.7						3	4	3.5	3			3.0	3.5
26 makes data available in a known format				3	4		3		3.3						4	4	4.0	3	4		3.5	3.6
27 makes data available in appropriate medium				3	4		2		3.0						4	4	4.0	3	4		3.5	3.4
28 makes data easily accessible				4	4		2		3.3						4	3	3.5	3	3		3.0	3.3
29 uses IT consistently				3	3		2		2.7						3	3	3.0	4	4		4.0	3.1
30 promotes reuse of historic test run data				2	2		1		1.7						3	1	2.0	3	4		3.5	2.3

E

Quality characteristics

Quality issues gathered at workshop held 25 June 1995 with WT personnel

ReqID	PostIt text	Justification/comment
K100	Relationships weakened through tunnel moving further away from Aero staff	used to be closer - moved to other side of airfield
K101	Priority-setting: WT act as middle man between projects	WT caught in battle between projects for resource
K102	Inexperience - Aero over-specify test runs (not very good at specifying test runs)	
K103	Turnover of Aero staff leads to a lack of continuity/understanding of WT capabilities	
K104	WT staff are longer term positions - culture differences between Aero and WT	
K105	Aero staff should be closer to WT - geography does have an affect - Warton are further away than Brough (separated by a runway)	
K106	Unrealistic expectations of WT (e.g., the number of runs demanded)	
K107	Aero always have work to be done - but cannot get them done due to lack of project funding - lost opportunity with idle WT	
K108	Cost too high! (charged back to a project).	A project manager concerne rather than Aero
K109	Not enough data fast enough	
K110	Aero concerned with data quality - relaible? accurate?	
K111	Aero Warton don't come over as much as they used to	change in staffing? type of test (ad hoc or std?)
K112	Responsiveness - how quickly can a test be scheduled, executed	

Quality characteristics gathered at workshop held 25 June 1995 with WT personnel

ReqID	PostIt text	Justification/comment
P100	Test run prioritization	
P101	Number of runs per week	Aero are charged on occupancy of tunnel - not number of runs
P102	Test complexity	no. of systems, no. of parameters per system
P103	Number of systems used	
P104	Cost estimation	
P105	Corrections applied correctly	
P106	Suitability of tunnel for test	
P107	Range of WT speeds	
P108	Absolute or incremental	compare two models for incremental
P109	Attitude range	
P110	WT data ties up well with flight test data	
P111	Continuity of speed range	
P112	Emergency WT test run service	
P113	Repeatability check	during run and across runs
P114	Calibration back to a benchmark	
P115	Scalability of data	experience of Aerodynamicist in scaling from model to full-size
P116	Operator should use software and not be aware of it - concentrate on test and model	
P117	Accuracy - individual (computer programs, model, tunnel flow, instrumentation/measurements) and overall accuracy	
P118	Online computing - degree of independence from IBM mainframe. Customer looks ata data and makes decision in RT	
P119	Did test run go as intended? model configuration, speed, sting movement	
P120	design of software (DAS) is key - run rate, operator error, configuration checks	
P121	Photograph model to verify configuration	subtle changes in store position can be captured
P122	Time taken to QA preliminary data to produce final data	could release as prelimianry and then make final
P123	Estimate time taken to produce an estimate	availability of estimate less first contact time

Service Quality Characteristics - Version QC1				
1st level	2nd level		3rd level	source
Test management	Estimating & Scheduling	1	reliability of test series estimation	P104, P100
		2	speed of production of test series estimate	P123, P102
		3	lead time for scheduling of test series	P112
	Test plan	4	rate of changes to specification	CE
		5	suitability of tunnel for test run	P106
	Test run execution	6	utilization of Aero staff time	CE
		7	rate of operator errors during test run	P120, P116
		8	rate of model configuration errors	CE
		9	correct processing of data	CE
WT management	Staff	10	level of WT operation experience	P119
		11	level of aerodynamic knowledge	CE
		12	satisfaction of Aero in dealing with WT staff	CE
	Communications	13	speed of response to customer contacts	CE
		14	level of awareness of Aero of WT staff responsibilties	CE
	Use of computing	15	level of manual intervention	CE
Models	Models	16	model correspondence to drawing	CE
		17	completeness of model inventory	CE
Facilites	Facilities	18	range of WT facilities	P101
		19	level of WT throughput	CE
	Tunnels	20	tunnel tolerances	CE
		21	tunnel parameters	P111, P109, P107
		22	tunnnel flow uniformity	P117

Product (data) Quality Characteristics - Version QC1				
1st level	2nd level		3rd level	source
data management	structure	1	redundancy	RV
		2	integrity	RV
		3	completeness	RV
	security	4	security	RV
	definition	5	data definition completeness	RV
		6	data definition correspondence	RV
		7	data definition accessibility	RV
	independence	8	hardware independence	RV
		9	application software independence	RV
		10	systems software independence	RV
	duplication	11	data duplication	RV
		12	processing duplication	RV
data usability	accuracy	13	absolute accuracy	RV
		14	comparison to flight test	RV
	availability	15	timeliness	RV
		16	retention policy	RV
		17	range of media	RV
	traceability	18	traceability	RV
	repeatability	19	same tunnel, same model, different time	RV
		20	same model, different tunnel	RV

Information System Quality Project

Quality Characteristics Dictionary

September 1995

Richard Vidgen (University of Salford) and the
Wind Tunnels Department (BAe)

Service quality characteristic no:	1
Quality characteristic title:	*reliability of test series estimation*
Source:	P104, P100

Quality characteristic description:

How good are the WT estimates of the cost and elapsed time of conducting a WT test series?

Assessment:

1. Estimated £ cost - Actual £ cost
2. Estimated elapsed time - Actual elapsed time

Target:

1. (Actual cost- Estimated cost) / Estimated cost < 5%
2. (Actual elapsed time - Estimated elapsed time) / Estimated elapsed time < 5%

Service quality characteristic no:	2
Quality characteristic title:	*speed of production of test series estimate*
Source:	P123, P102

Quality characteristic description:

How long does it take WT to produce an estimate for a test series?

Assessment:

Date estimate available - Date estimate received

Target:

Category A	Simple test series	2 working days
Category B	Medium complexity tests series	4 working days
Category C	Complex test series	6 working days

Service quality characteristic no:	3
Quality characteristic title:	*lead time for scheduling of test series*
Source:	P112

Quality characteristic description:

How well do WT schedule test runs to meet the timescales of the Projects?

Test series are categorized as standard or ad hoc. Standard requests are scheduled in line with Project priorities. Ad hoc test series take precedence over scheduled work and have immediate access to WTs, subject to authorization.

Assessment:

Standard project required start date - WT offered date

ad hoc	time tunnel requested - time tunnel available

Target:

Standard:	plus or minus 5 working days
ad hoc	2 hours

Service quality characteristic no: 4

Quality characteristic title: *rate of changes to specification*

Source: CE

Quality characteristic description:

How many changes are requested to the test plan by Aero following sign-off the test plan specification? These changes can take place pre-test run or in-test run.

Assessment:

Pre-test run	no. of changes requested due to incompleteness of plan
	no. of changes requested due to errors in plan
In-test run:	no. of changes requested due to incompleteness of plan
	no. of changes requested due to errors in plan

Target:

Pre-test run	no. of changes requested due to incompleteness of plan	0
	no. of changes requested due to errors in plan	0
In-test run:	no. of changes requested due to incompleteness of plan	0
	no. of changes requested due to errors in plan	0

Service quality characteristic no: 5

Quality characteristic title: *suitability of tunnel for test run*

Source: P106

Quality characteristic description:

How suitable was the tunnel (facility) for a test run/series?

Assessment:

Target:

Service quality characteristic no: 6

Quality characteristic title: *utilization of Aero staff time*

Source: CE

Quality characteristic description:

How much of Aero time is not utilized effectively while a test run is in progress?

Assessment:

1. Time spent travelling to WT facility
2. Time spent in tunnel when not required

Target:

Service quality characteristic no: 7

Quality characteristic title: *rate of operator errors during test run*

Source: P120, P116

Quality characteristic description:

How many operator-related errors are made during a WT run?

Assessment:

1. Data entry errors
2. Model and tunnel configuration errors

Target:

Service quality characteristic no: 8

Quality characteristic title: *rate of model configuration errors*

Source: CE

Quality characteristic description:

How many errors are made in model configuration?

Assessment:

1. Errors notified during run
2. Errors notified after run complete and data released

Target:

Service quality characteristic no: 9

Quality characteristic title: *correct processing of data*

Source: CE

Quality characteristic description:

Are the data-processing suites run the same as those specified?

Assessment:

1. Rate of incorrect selection of data-processing suites
2. Rate of incorrect parameter input to data-processing suites.

Target:

Service quality characteristic no: 10

Quality characteristic title: *level of WT operation experience*

Source: P119

Quality characteristic description:

How much experience do the operators have of WT operation?

Assessment:

1. Years of experience as operator
2. Years of experience as project supervisor

Target:

Service quality characteristic no: 11

Quality characteristic title: *level of aerodynamic knowledge*

Source: CE

Service quality characteristic description:

How much experience/knowledge do the operators and supervisors have of the theory and practice of aerodynamics?

Assessment:

Target:

Service quality characteristic no: 12

Quality characteristic title: *satisfaction of Aero in dealing with WT staff*

Source: CE

Quality characteristic description:

How satisfied are Aero with their dealings with WT? This relates to service quality.

Assessment:

A service quality questionnaire adminstered at least once a year.

Target:

Service quality characteristic no: 13

Quality characteristic title: *speed of response to customer contacts*

Source: CE

Quality characteristic description:

How quickly do WT respond to Aero contacts?

- telephone calls
- fax
- email
- written correspondence

Assessment:

Target:

Service quality characteristic no: 14

Quality characteristic title: *level of awareness of Aero of WT staff responsibilities*

Source: CE

Quality characteristic description:

How aware are Aero of the organization structure and the day to day contacts at WT?

Assessment:

Target:

Service quality characteristic no: 15

Quality characteristic title: *level of manual intervention*

Source: CE

Quality characteristic description:

How much manual intervention is required in the cycle of estimating, scheduling, executing, and delivering?

Assessment:

Target:

Service quality characteristic no: 16

Quality characteristic title: *model correspondence to drawing*

Source: CE

Quality characteristic description:

How well does the model correspond to the drawing it is based upon?

Assessment:

Target:

Service quality characteristic no: 17

Quality characteristic title: *completeness of model inventory*

Source: CE

Quality characteristic description:

How complete is the model inventory? How well do the models correspond to the inventory? How good is the condition of the models?

Assessment:

Target:

Service quality characteristic no: 18

Quality characteristic title: *range of WT facilities*

Source: P101

Service quality characteristic description:

How wide is the range of WT facilities?

Assessment:

Coverage of standard WT facilities

Target:

Service quality characteristic no: 19

Quality characteristic title: *level of WT throughput*

Source: CE

Quality characteristic description:

How high is the throughput of the WTs?

Assessment:

Runs per week

Target:

Service quality characteristic no: 20

Quality characteristic title: *tunnel tolerances*

Source: CE

Quality characteristic description:

Within what tolerances does the tunnel operate?

Assessment:

Target:

Service quality characteristic no: 21

Quality characteristic title: *tunnel parameters*

Source: P111, P109, P107

Quality characteristic description:

How flexible are the tunnel parameters?

Assessment:

- sampling rate
- data range continuity
- model attitude range
- tunnel speed range
- Reynolds number range

Target:

Service quality characteristic no: 22

Quality characteristic title: *tunnel flow uniformity*

Source: P117

Quality characteristic description:

How uniform is the flow of the tunnel?

Assessment:

Target:

Product quality characteristic no: 1

Quality characteristic title: *redundancy*

Source: RV

Quality characteristic description:

Redundancy occurs where the same data is stored in more than one place. This is usually the result of unnormalized data structures. Some redundancy is to be expected in data structures, but it must be recognized and controlled.

Assessment:

Target:

Product quality characteristic no: 2

Quality characteristic title: *integrity*

Source: RV

Quality characteristic description:

Integrity errors occur, for example, when it is possible to assign a test run to a model that does not exist in the model file, or to assign a non-existent operator to a test run.

Assessment:

Target:

Product quality characteristic no: 3

Quality characteristic title: *completeness*

Source: RV

Quality characteristic description:

Completeness is the degree to which all data concerning an entity is represented in the data. For example, are all models in the database, are all staff entered into the database.

Assessment:

Target:

Product quality characteristic no: 4

Quality characteristic title: *security*

Source: RV

Quality characteristic description:

Security includes access privileges (create, read, update, delete); disaster recovery; network security, etc.

Assessment:

Target:

Product quality characteristic no: 5

Quality characteristic title: *data definition completeness*

Source: RV

Quality characteristic description:

The data definition is given by the object model. This shows the classes needed to represent aerodynamic data and test runs. The completeness of the logical model is assessed in light of the processes that it is intended to support.

Assessment:

Target:

Product quality characteristic no: 6

Quality characteristic title: *data definition correspondence*

Source: RV

Quality characteristic description:

How well does the data in the computer system correspond to the logical and physical data models?

Assessment:

Target:

Product quality characteristic no: 7

Quality characteristic title: *data definition accessibility*

Source: RV

Quality characteristic description:

Is the logical and physical data model available to users? For example aerodynamicists may wish to see the meaning of a particular attribute. For some attributes it is necessary to know the measurement scale used to make a recording, such as tunnel speed.

Assessment:

Document the data model and maintain a dictionary.

Target:

Product quality characteristic no: 8

Quality characteristic title: *hardware independence*

Source: RV

Quality characteristic description:

How much effort is needed to to move the data and processing from one platform to another, e.g., from mainframe to work-station.

Assessment:

Target:

Product quality characteristic no: 9

Quality characteristic title: *application software independence*

Source: RV

Quality characteristic description:

How much effort is needed to move from one set of application programs to another? For example, could a third party plotting package be introduced?

Assessment:

Target:

Product quality characteristic no: 10

Quality characteristic title: *systems software independence*

Source: RV

Quality characteristic description:

How much effort is needed to move from one database management system (DBMS) to another (e.g., ADABAS to Oracle), or to change the networking software, or to migrate to another operating system.

Assessment:

Target:

Product quality characteristic no: 11

Quality characteristic title: *data duplication*

Source: RV

Quality characteristic description:

How many times is data copied around the organization? Copies may need to be taken for use in local offices, but copying of data should be minimized wherever possible.

Assessment:

Number of copies.

Target:

Some items of data get copied up to 35 times. Most data is copied 5 or 6 times. A target might be to have no more than three copies of WT data.

Product quality characteristic no: 12

Quality characteristic title: *processing duplication*

Source: RV

Quality characteristic description:

Is the same piece of processing performed by more than one program? For example, different programs in different tunnels, different programs on different hardware platforms, and even different programs in the same tunnel and same platform. Duplication should be eliminated wherever possible and must be controlled where duplication is unavoidable.

Assessment:

Number of programs implementing a function.

Target:

Product quality characteristic no: 13

Quality characteristic title: *absolute accuracy*

Source: RV

Quality characteristic description:

How accurate are the tunnels in absolute terms?

Assessment:

Against what is the tunnel to be compared? Benchmarks against third party tunnels might be performed.

Target:

Product quality characteristic no: 14

Quality characteristic title: *comparison to flight test*

Source: RV

Quality characteristic description:

How well does the data produced match to flight test data?

Assessment:

Predictive ability of WT test data.

Target:

Product quality characteristic no: 15

Quality characteristic title: *timeliness*

Source: RV

Quality characteristic description:

How quickly can WT deliver test run (processed data) data to Aero?

Data states to be monitored:

- In-test produced concurrently with test run
- Category A provisional data
- Category B data checked by WT
- Category C data approved by Aero

Assessment:

In-test: time data available - time data collected

Post-test: time data available - time test run completed

Target:

In-test data	real-time with data collection: 0.5 second
Category A	5 minutes
Category B	4 hours
Category C	1 week

Product quality characteristic no: 16

Quality characteristic title: *retention policy*

Source: RV

Quality characteristic description:

How long is test run data retained for access by Aero?

Assessment:

Retention period

Target:

For example, 25 years

Product quality characteristic no: 17

Quality characteristic title: *range of media*

Source: RV

Quality characteristic description:

How many different medium can WT supply data to Aero in?

- point data
- graphical output
- video
- flow-visualization

Assessment:

Target:

Product quality characteristic no: 18

Quality characteristic title: *traceability*

Source: RV

Quality characteristic description:

Is is possible to recreate the circumstances surrounding the test run data. For example, to establish the precise model configuration, the operator, any events that were noted in the test run log book, tunnel calibration, tunnel temperature.

Assessment:

Target:

Product quality characteristic no: 19

Quality characteristic title: *repeatability - different time*

Source: RV

Quality characteristic description:

Repeatability of data - same model, same tunnel, different time.

Assessment:

Target:

Set a repeatability tolerance

Product quality characteristic no:	20
Quality characteristic title:	*repeatability - different tunnel*
Source:	RV

Quality characteristic description:

Repeatability of data - same model, different tunnel, different time.

Assessment:

Target:

Set a repeatability tolerance