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Afterword: The past, present and future of sociotechnical systems theory

1. Introduction

It is a rare privilege to have been the inspiration behind the production of this collection of papers and I warmly thank all of the contributors, especially Patrick Waterson, for reminding me of so many debates and giving me so much to reflect upon. I was especially pleased to find such a strong theme running through these papers, a theme that has been an obsession for me for over 40 years: sociotechnical systems theory. Throughout my career I have been concerned with systems approaches in ergonomics because they enable us to recognize that people at work often engage in tasks as part of a complex system and this has profound effects on them and their task performance. Of all the systems approaches that are available I have found sociotechnical systems theory the most powerful way of explaining systems behaviour and the most useful in designing new systems. My aim in these pages is to use the insights that the authors in this volume have provided to reflect on what has been important to me about sociotechnical systems theory, on where this approach is in the present day and what contribution it might make in the future.

2. Sociotechnical systems studies 1970–1990

I was very fortunate in the 1970s to work with Lisl Klein and Harold Bridger who were at that time stalwarts of the Tavistock Institute of Human Relations in London, widely acknowledged to have been responsible for the development of sociotechnical systems theory. The theory was developed to explain the human and organisational ramifications of the introduction of mechanization into coal mining, weaving and other industries. By the 1970s it was computer technology in all its forms that was beginning to have a major impact on work systems and when we started the HUSAT (Human Sciences and Advanced Technology) Research Group at Loughborough University, so graphically described by Tom Stewart and Leela Damodaran (Waterson, Stewart and Damodaran, this volume), it was natural for me to apply sociotechnical systems concepts in order to understand the impact of this new technology on people at work. At that time the main issue was that this technology was being used via 'remote terminals' linked to mainframe computers by 'naïve users', i.e. people who were not computer professionals, and these new users had to adapt to the unfriendly, rigid and literal ways in which computers operated. This started a major programme of work to render these devices easy to use for their new users leading to the 'user friendly' graphical interfaces used by most of the population today. My preoccupation, however, was that within each organisation there were different kinds of users whose work roles and tasks required a specific service from the computer system. As a consequence we were soon writing papers about the needs of different kinds of computer user and my contribution to an early issue of this journal was a paper on 'the manager as a computer user' (Eason, 1974). Sociotechnical systems theory, because of its emphasis upon the way technical and human resources are deployed to serve the needs of a collective task, was particularly well suited to examining how effectively the task needs of each user were served by computer systems and in most cases we found they were very badly served with the result that many systems were either rejected or 'worked around'.

In its earliest manifestations sociotechnical systems theory was used to analyse existing systems and it was a very useful way of revealing dysfunctions between what people in the social system were trying to achieve and what the technical system facilitated or inhibited. It is a short step from this kind of analysis to trying to influence design so that a more effective sociotechnical system can result and in HUSAT that led to a series of major initiatives to create sociotechnical methods for the design of computer-based work systems. Such systems cannot be designed without the engagement of the people who will use them so a major strand of this work was to develop user participative methods for new systems design. These objectives led to a series of methodological developments, for example, in the HUFIT project (Galer et al., 1992), in systems developments for Government Departments (Damodaran, 1996) and in the ORDIT project (Eason et al., 1996) which developed methods for organisational requirements specification at the beginning of systems development. We were also closely associated with other attempts to develop methodologies for the sociotechnical design of information systems, for example ETHICS (Mumford, 2000) and Multiview (Bell and Wood-Harper, 2003).

Whilst we were moving in this user-centred direction with the growing influence of computer technology as our motive force, the Tavistock Institute of Human Relations and others were also developing sociotechnical systems theory as a design approach. But in this case there was another important element: there was a concern for the quality of working life and that sociotechnical systems should embody the principles of democratization of work. In practice this meant that, when sociotechnical systems theory became very popular in Scandinavia, it was almost synonymous with the application of semi-autonomous work groups; work teams that had a great deal of discretion over how they undertook their collective tasks. This approach became most well known through its application by Volvo in the Kalmar Car Assembly Plant in Gothenburg, Sweden where the paced assembly line was replaced by assembly cells in which semi-autonomous work groups had discretion to undertake major assembly tasks (Hammarstrom and Lansbury, 1991).

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In this period sociotechnical ideas began to spread around the world and perhaps retained their greatest coherence through attempts to set down the principles underpinning the approach, for example Cherns (1976, 1987) and Clegg (2000), both of whom focus more on sociotechnical design than upon the use of the theory for systems analysis.

3. Sociotechnical systems theory in the present day

In the past decade the sociotechnical approach appears to have become a term in common currency in a number of different disciplines concerned with the world of work. In this volume, for example, there are contributions from ergonomics, psychology, human–computer interaction, sociology, management and organisational theory. Even this range does not convey all the domains where the approach is having a significant impact. Many researchers are now, for example, taking a sociotechnical approach to the design of safety critical systems (Carayon and Karsh, 2000; Leveson, 2012). And research into the burgeoning field of social networking is making considerable use of sociotechnical concepts, see for example the two volume 'Handbook of Research on Socio-Technical Design and Social Networking Systems' (Whitworth and de Moor, 2009). The analysis by Neil Doherty (Doherty, this issue) of concepts in Benefits Realisation Management (BRM) suggests also that, as knowledge spreads, the origins of concepts can be lost. Doherty suggests that the systems concepts in BRM bear too strong a resemblance to sociotechnical systems concepts for it to be accidental but that the term 'sociotechnical' has been lost in the process of generating this new framework.

It is possible to take two contrasting views of these developments. On the one hand they seem to show that sociotechnical systems theory has been very successful; that it is an approach of immense utility, providing tools and insights to people making a wide variety of contributions to systems design. On the other hand, it may be that, in its spread into many different domains, if it is remembered at all, it has been diluted to a cypher; a banner under which many different concepts and design principles can flourish that have little relation to one another. Reviewing the use of the term 'sociotechnical' across many different domains today one can find many interesting and valuable contributions but it can, in many cases, be difficult to see what they have in common; what shared conceptual roots they spring from. There is, ironically, for example, no agreement about the basic issue of the hyphen: are we dealing with socio-technical systems or sociotechnical systems?

I rejoice in the diffusion and popularity of the sociotechnical 'brand' but I fear for what we may be losing in the process. It may be that the price of diffusion of the sociotechnical approach is dilution of the conceptual foundations that marked its beginnings. In some cases 'sociotechnical' is a term used to refer to any circumstance where a number of people make use of a common technology. In other cases it means that theoretical attempts have been made to explain sociotechnical phenomena in particular domains that have not been related to the original conceptual foundations. If we are to make scientific progress it must of course be the case that new theoretical explanations are advanced to deal with emergent challenges in each domain. But it would be wasteful at the very least if in the search for the new we ignore valuable lessons from the past. Sociotechnical systems theory has a well-articulated theoretical foundation and it is this that seems in most danger of being lost. Reading these papers has caused me to reflect on what I have found most valuable in the approach and what I feel will continue to be of most relevance in the rapidly changing world of work. In the next sections I have attempted to articulate what I see as the most valuable insights to carry forward into future developments and uses of the theory.

4. Sociotechnical concepts for the future

Several of the papers in this collection look forward to future challenges for sociotechnical systems theory. Niels Bjørn-Andersen and Benoit Raymond (Bjørn-Andersen and Raymond, this issue) make the important point that work organisations are changing their character and, as a result of the growing use of IT, are becoming more 'ambient' in their character as more work processes are undertaken by networks of suppliers. Traditionally sociotechnical systems design has concerned itself with the development of work systems inside a particular host organisation and the challenge now is to look at work systems that extend across a number of organisations. As Lisl Klein remarks in her paper (Klein, this issue), the issue of where the boundaries are drawn for any system has always been important in sociotechnical systems work, i.e. whether it is a work team or a factory or a whole organisation. In the future it seems, in order to continue to be relevant, the theory has to embrace trans-organisational work systems. In their paper Matthew Davis and colleagues (Davis et al., this issue) call for sociotechnical systems theory to address new types of systems that involve both social and technical components such as crowd control and sustainability. I am also aware of developments in sociotechnical systems theory that are being made by researchers studying emerging forms of new technology, for example, social media systems in which potentially all communications between people in the social system are mediated by the technical system (see for example Heeney (2009) and Tuffley (2009). New technology is changing the way we work and communicate with one another and, if sociotechnical systems theory is to be of continuing value, it needs to rise to these challenges.

I believe there are significant aspects of sociotechnical systems theory that will enable it to make important contributions to the changing nature of work systems in the future. The following sections examine five concepts and methods that have these enduring characteristics.

4.1. Task interdependencies in sociotechnical systems

All systems theories are about the interdependencies between the components of a system. Sociotechnical systems theory is no exception but there is one kind of interdependency that is of particular significance. Sociotechnical systems theory has traditionally been concerned with work systems in which a number of people have a role to play in a collective task be it coal mining, car assembly or care for the sick. Engagement with a large task leads to division of labour between the people involved and this produces task interdependencies between them; in teamwork, for example, you are helped or hindered in your work by the work of other team members. Understanding the task interdependencies intrinsic to a large task is at the heart of a sociotechnical systems analysis and is particularly useful, for example, in exploring the implications of a proposed change. Matthew Davis and his colleagues (Davis et al., this issue) call for sociotechnical approaches to be used for predictive work and one way of doing this is by following the impact of change through the task interdependencies as they ripple through the system. In this way, what usually emerge as 'unexpected and unwanted consequences' after a change has been implemented, can be predicted long before when corrective action can be taken.

Patrick Waterson (Waterson, this issue) reports the work we have undertaken over many years on the implementation of electronic patient records in the UK National Health Service. This began with the launch of the massive National Programme for IT (NPfIT) in 2004 that was to deliver standard electronic records across all the health agencies of England in order that they could share patient information. Having undertaken a top-level sociotechnical systems analysis (Eason, 2005, 2007) it was relatively easy at an early stage to predict the problems that would beset this programme as it tried to adopt a 'one size fits all' strategy to serve users in very different task environments ranging from general practice, mental health and maternity services to cancer surgery. It was not so easy, however, to stop this national juggernaut and we have now had plenty of opportunity to see these predictions come true as Patrick Waterson has illustrated. In a recent study (Eason and Waterson, 2013) we have undertaken an analysis of the different kinds of interdependencies that exist in healthcare tasks to explore what kinds of electronic information sharing might be appropriate in different contexts. It will, I am sure, be of continuing relevance to whatever work systems exist in the future to undertake this kind of analysis before launching into change programmes.

The analysis of task interdependencies also has implications for sociotechnical design. Where, for example, there is a dense set of tight interdependencies the people engaged in those tasks need to work closely together. This situation is therefore a very good candidate for the development of an autonomous work group.

4.2. Sociotechnical systems as open systems

One of the most famous papers in sociotechnical systems theory is about the impact of the environment on a sociotechnical system (Emery and Trist, 1965) and the recognition that a work system has to be treated as an open system. Any work system has inputs coming in from the outside world and is exporting goods or services. It is also subject to a wide range of environmental factors from physical disturbances to financial, market, regulatory and technical developments. As a result the work system has to be capable of responding to a lot of variance; to be resilient so that it can respond appropriately to the different demands made upon it. One of the features of a sociotechnical systems analysis is an assessment of the particular environmental factors that have the most impact on the system and what implications they have for the transmission of variance through the task interdependencies in the system.

One of the issues created by the openness of a system is that it can make it problematic to define the boundaries of a sociotechnical system. You can bring many of the important environmental influences within the boundary and treat them as part of the sociotechnical system and susceptible to design change. Or you can leave them outside of the boundary where they cannot be changed and the system inside the boundary has to be designed to cope with any turbulence caused by the environmental factors. In her paper Lisl Klein (Klein, this issue) gives the example of two teams working on oil tanker design in which the ergonomics team adopted a narrow boundary, around the control room of the tanker, whilst a team of social scientists chose a wide boundary that encompassed everything about the oil industry. Both can be appropriate depending on what a particular study sets out to achieve. The ORDIT (Organisational Requirements Definition for IT Systems) methodology (Eason et al., 1996), which is about defining the scope for sociotechnical systems change, starts by engaging the significant stakeholders in the question of where to set the boundary. In practice, answering this question usually involves determining the collective task that binds the sociotechnical system together and helping stakeholders to establish where they have leverage to redesign the existing sociotechnical system.

It used to be the case that the boundary was typically set within a single organisation but, as the analysis by Niels Bjørn-Andersen and Benoit Raymond (Bjørn-Andersen and Raymond, this issue) shows we are increasingly moving into a world where complex tasks are undertaken by a number of different organisations contracted to work together. This is to be seen most clearly in supply chain arrangements and in organisations that contract-out key functions to other organisations. However, there are also many other examples where a variety of organisations need to work together in real-time to undertake the collective task: Matthew Davis and colleagues (Davies, this issue), give the example of all the agencies that work together on crowd control and Dave Wastell and Sue White (Wastell and White, this issue) discuss the way social care professionals need to work with the police, teachers, healthcare specialists and the legal profession to achieve their shared task of keeping children safe. Recently I have been working with Patrick Waterson (Eason and Waterson, 2012) in a similar domain, the integrated health and social care of the elderly in the community. This is a shared task that can involve many different agencies. The current 'sociotechnical system' for accomplishing it is, in many places, so highly fragmented that it does not have many of the characteristics of a system. As a result many elderly people receive unconnected services that do little to answer their real needs. It seems very clear that there are two major tasks for the development of sociotechnical systems theory in the future: to analyse multi-organisational task performance in complex open systems and to develop a design approach that can apply across organisations.

4.3. The role of people as system 'resources'

Sociotechnical systems are, by definition, heterogeneous systems: that is, they are constituted of components with very different characteristics. In this case the social system, composed of people, is completely different from the artifacts that make up the technical system. The social system, for example, unlike the technical system, is made up of sentient 'components' aware of their environment and capable of generating new behaviour patterns in responses to the changes they perceive. And yet both kinds of system component must work closely together if the system is to function well. The interrelations that govern system behaviour extend in several directions: in task interdependencies in the work to be done, between the people who share the work, between the technical components in what might be more or less integrated technical systems and between humans and technology at many different levels. One way of expressing how sociotechnical systems work is to say that the work needed to undertake all the tasks needed to complete the collective task is done by two kinds of resources: human resources and technical resources. Human beings are thus components in the work performing system, taking responsibility for particular tasks and turning their energy and skill into performing those tasks. All across the world organisations have 'Human Resources Departments' so we should not be surprised by the view that people are resource components in sociotechnical systems. And yet the term is problematic because people are so much more than resource components in a system: they are beings with many other roles outside work, they have motives, anxieties and emotional states that often impact on their work, they are learning and adapting organisms and many other things besides. In sociotechnical systems theory recognition that people have these properties has focused on motivation to work, job satisfaction, well being at work and industrial democracy. Whilst these concerns will remain important in the future, I want to focus on another feature that distinguishes human 'resources' from the technical resources in sociotechnical systems. I refer to the adaptive and learning capabilities of people and I want to link these abilities to participatory ergonomics because they mean people are not just resources in a work system but are also designers of work systems.

Open systems have to be resilient and adaptive to cope with the challenges of turbulent and changing environments. How are we to render sociotechnical systems resilient and adaptive? Although the technical components in work systems are becoming ever more sophisticated they have nothing like the capability of people to appreciate the need for change and to learn and adapt, and it is only through mobilizing these capabilities that we can hope to develop resilient and adaptive work systems. However, the role of technology in sociotechnical systems is becoming increasingly pervasive and, although it can be used to enhance the human role in systems, it is often the case, for example, through the use of automation and expert systems, that the technical system serves to inhibit the use of human learning and adaptability. There are several examples of the way technology can become a barrier to the full use of human capabilities at work in the papers in this issue. Lisl Klein (Klein, this issue) reminds us, for example, of situations where automation makes it difficult for people to deal directly with the task in hand and therefore difficult for them to respond appropriately in emergency situations. In a different context Dave Wastell and Sue Cox (Wastell and Cox, this issue) have analysed the impact of Integrated Children's Systems on social care workers and found that these systems are a barrier to the development of a full understanding of the case notes of the children in their care (see also Broadhurst et al., 2009; White et al., 2010). In our work on electronic patient information systems (Eason and Waterson, 2013) we have obtained similar findings: these records are usually highly structured, predefined and coded and are often of little help in dealing with complex cases where patients have ill-defined and multiple conditions to treat. In these latter cases part of the problem is that the technology is being introduced as a control mechanism to enforce standardized practices and is therefore intended to minimize the scope for human initiative. A common finding of studies of the use of these systems is that there are lots of 'workarounds' as users find ways of meeting task requirements by bypassing the way the technology works. Human learning and adaptability is in evidence but it is being used primarily to workaround the technical systems. In an optimal sociotechnical system it should surely be the other way round: the technical system should be working to promote human learning and adaptability.

But there is plenty of evidence that if sociotechnical systems design principles are adopted we can use modern technical systems to aid people in their collective work on tasks and to support their efforts to respond to new challenges. In his paper Martin Maguire (Maguire, this issue) provides examples of the many different types of computer-based technology that can now provide powerful and flexible support for teams of people working on shared tasks. And Dave Wastell and Sue White (Wastell and White, this issue) provide some very interesting examples of alternatives to the Integrated Children's Systems that use the technology to support people as they deal with the messiness of a collection of disparate information in the case files about a child. Technical systems can be created to support people at work but so often this does not happen which takes us back to the design process by which sociotechnical systems are created; a theme I will return to at the end of these reflections.

4.4. Analysis, evaluation, prediction and design

In a journal with the title 'Applied Ergonomics' it is appropriate to reflect on how methods and theories can be deployed to do practical work and, in reading the papers, I was struck by the different practical contributions sociotechnical systems theory is making which I have classified as analysis, evaluation, prediction and design.

4.4.1. Analysis

I have found sociotechnical systems theory very useful in analyzing the effectiveness of existing work systems in achieving their objectives. It is important to note that the theory can be used to describe and assess any work system and that this is very different from using it as a design methodology where the aim is to follow design principles to create a system that jointly optimizes the social and technical subsystems. In my career I have been able to undertake sociotechnical systems analyses of many different work systems, from manufacturing to service delivery and healthcare. The managers of these systems are often trying to tackle specific symptoms of failure such as low quality, high accident rates, poor local management etc. After a sociotechnical analysis has been undertaken they are often surprised to find that there are systemic issues underlying these symptoms, for example, technology not well suited to the tasks staff are actually undertaking. In one case we studied a warehouse in East London (Mars, 2009) where the presenting problem was a very high rate of pilferage. What the analysis revealed was a sociotechnical system that had evolved through a series of actions by a local, highly unionized, workforce that enabled collusion to occur in some work teams to support well organised pilfering. This was a case of a team structure developing that was actively working against the task objectives of the overall work system.

In this collection Theoni Koukoulaki (Koukoulaki, this issue) reports an analysis of a number of studies that have examined the impact of lean production on the stress levels of people at work. This is an example where a very significant form of technical system, (lean production) is suspected of having a detrimental effect on the social system. In practice what the evidence shows is that lean production is made up of a bundle of different technical tools, from just-in-time (JIT) production to quality circles, and some of these practices, notably JIT, have direct task implications for the autonomy of workers and can lead to heightened stress levels. This is a reminder of the fallacy of the old concept of 'technical determinism'; we cannot treat any form of technology as though it has a fixed impact on the social system. There are almost always many variants of the technology and it is this flexibility that makes it possible to design a combined sociotechnical system where there is a better fit between the technical and social components.

4.4.2. Evaluation

Probably the most common way of utilizing sociotechnical systems theory is as a summative evaluation framework for assessing what happened when a major change, usually a new technical system, was made to a work system. This was the nature of the studies that gave rise at the Tavistock Institute of Human Relations to the original form of sociotechnical systems theory: seeking to explain the response of the social systems in coal mining and weaving mills to new forms of mechanization. And many of us have followed in this tradition by evaluating how work organisations have responded to the implementation of new information and communication technologies. What these studies have shown repeatedly is that there is a very big difference between implementing a new technical system and it being adopted as a full functioning part of the work system. Neil Doherty (Doherty, this issue) provides some of the statistics about the level of failure to adopt new systems, for example, a study by Shpilberg et al. (2007) showing that only 16% of IT projects can be considered truly successful. Patrick Waterson (Waterson, this issue) identifies many healthcare IT projects that have come to grief, not only NPfIT in England but many other health information technology projects around the world. Sometimes the outcome is total rejection of the technical system but more often there are forms of partial adoption; some features of the system are adopted by some of the workforce for some purposes, and often not the purposes envisaged by the system designers. If people have limited discretion and have to use the system, then we see the development of workarounds to keep the technical system in play whilst also keeping the work flowing.

In all these responses we can see two things. First, technical systems have to work as parts of sociotechnical systems and adoption cannot be effective (and the benefits of the technology realized) unless the capabilities of the technical system can be effectively exploited by the social system in the performance of tasks. Secondly, even if social system considerations do not play a big part in the design and implementation of the technical system, it is the actions of the workforce subsequently that determine what part the technical system plays in the working sociotechnical system. Whether or not they were involved in the early stages of design, the workforce are in many ways the de facto 'designers' of the system that actually does the work.

In my book on the relation between IT and organisational change (Eason, 1988) I presented a series of propositions about the way the adoption of new technical capabilities by a social system should be undertaken if an effective sociotechnical system was to result. In his analysis of the relation between sociotechnical systems theory and Benefits Realisation Management, Neil Doherty (Doherty, this issue) has reviewed these propositions and emphasizes the vital role the people in the system play because it is only through them that benefits can be realized.

4.4.3. Prediction

If we are able to show after a new technical system has been delivered that there have been problems with its adoption, perhaps as Matthew Davis and colleagues (Davis et al., this issue) propose, we could do more to use sociotechnical systems theory to predict the outcome of new systems plans whilst those systems are still in the design phase. In practice the theory has been used as a framework for this kind of formative evaluation in many circumstances and the findings constitute predictions of what would happen if the planned technical system was implemented in existing sociotechnical work system settings. And they have often led to major changes in planned technical developments.

Ideally formative evaluations of sociotechnical systems are carried out by implementing pilot or trial versions of new technical systems in real examples of existing work systems. This makes the implications of the new system evident to everybody and means subsequent user contributions to design are based on real experience of the technical system in question. In this approach it is not sociotechnical systems experts that are making predictions but the people who will be affected who do the predicting and who look for alternatives that will provide benefits and avoid systemic dysfunctions.

We have had several opportunities to undertake work of this kind. For example, a freightforwarding company was planning a nationwide computer system and we persuaded them to run pilots in two branches (Klein and Eason, 1991). The pilot showed that the new system would inhibit the entrepreneurial zeal with which local managers were used to doing deals with local customers, hauliers etc. After the pilots the company went back to the drawing board and adopted an approach that gave each branch its own computer system (and left discretion with the local management team). In an electricity distribution company the plan was to provide engineers with an expert system that would automatically prepare switching schedules: detailed programmes of network changes needed to undertake maintenance and other work on the electricity distribution system (Eason et al., 1995). Trial usage of this system quickly revealed that there was no way in which the local knowledge of engineers that normally went into the preparation of switching schedules could be incorporated if the system was used. With this new-found understanding of how the engineers actually worked, the designers re-thought the design, abandoned the concept of an expert system and developed a network planning assistant instead.

But perhaps the biggest trial of a new technical system we have undertaken was the SuperJournal project (Eason et al., 2000; Baldwin and Pullinger, 2000). This was a trial of electronic journals in the 1990s before these services were widely available. In this project a group of publishers worked with a systems supplier to deliver clusters of electronic journals on a trial basis to the academics and students of twelve UK Universities. We had an opportunity to log the usage of these journals and to interview everybody involved. The results showed very clearly what people did and did not want from this service. At the start of the trial there was a belief that, if they were to be successful, electronic journal articles would have to be different from paper-based ones. They could, for example, be full of animations, they could have 3-D models of data and findings etc or they could provide links to the researcher's original data. But the results showed that current journal articles in every discipline reflected the conventions and processes of that discipline and there was very little appetite for changing the way scientific progress was being reported. However, the users of journals could see that electronic journals would have important benefits; what they wanted was to be able to get the full text of articles wherever they were through their computers. This direction of development of technical services had profound implications for publishers, university libraries and the providers of the electronic services and the SuperJournal project ended with a series of workshops from which all the different stakeholders took these messages back to their organisations. And that is the dominant way electronic journal services have developed subsequently: we can now access the full text of journal articles wherever we are and they look suspiciously like journal articles have always looked. Behind the scenes, however, the sociotechnical system that delivers this service (the authors, editors, publishers, technical systems providers, libraries etc) has undergone many changes.

It is not always possible to set up pilots and trials because they can be expensive and time consuming which raises the question of how else we can make sociotechnical predictions. One technique that shows a great deal of promise is to create sociotechnical systems scenarios. We have asked the people who play significant roles in a work system to develop examples of their work and to depict how they all contribute to the work so that we have evidence of the work process and the social system engaged in the process. Then we overlay the scenario with the new technical system that is being planned. We then hold workshops with the people in the work process to step through the scenarios exploring as we go the implications of the new technology for each work role. This can be a very vivid way of bringing to life what the new sociotechnical system might be like and usually leads to active user participation as people explore whether the system could be changed to bring more benefits or avoid unwanted implications. Undertaking this process in electricity distribution showed, for example that a system for distributing new service tasks straight from a central control centre to the van of a service engineer would have considerable consequences for the engineer ("It will be like being managed by a van") and for their local foremen ("We will not know what is going on; we might as well go fishing") (Eason, 1996). Doing a similar exercise on the implications of lean manning on the social system of a new destroyer showed that many emergency operations would be difficult to undertake (Strain and Eason, 2000). And getting the staff of a mental health trust to explore the implications of implementing an electronic patient information system led them to question how it was going to help them coordinate their work rather than just adding another set of data inputting duties to provide management information (Eason, 2007). The ORDIT methodology (Eason et al., 1996) includes a phase in which users develop and evaluate sociotechnical options. There is an initial phase in which a sociotechnical model of the current work process is developed and in the next phase a number of new sociotechnical system scenarios are created that implement the stated requirements for change. The stakeholders then work through the sociotechnical implications before selecting the path they wish to take. It is a process that usually leads to a gradual change programme because the stakeholders become aware that there will be widespread ramifications if dramatic changes are introduced.

4.4.4. Design

For many sociotechnical systems theorists the primary aim of the theory is to further sociotechnical systems design. As a result there are now many design methods and principles that aim to create technical and social systems that are co-optimised in relation to the shared task of the work system. The theory includes many principles about job design that, for example, promote the idea of local autonomy so that the human resources in the system can adapt their task behaviour to suit changing circumstances. There seems no doubt that we are moving into a world where the work that most people do will be more and more mediated by computer-based technologies so it will be ever more important that future work systems are designed with co-optimisation as a major goal. There is a danger, for example, that people will only know their task though the way it is represented by the technology, the implications of which Lisl Klein illustrates so well in her contribution (Klein, this issue). It is also likely that people will only know the others they collaborate with in shared tasks through their computer-based communications. These two issues seem to me to call urgently for more use of sociotechnical systems theory to design systems that enable people to really know their tasks and the people they are working with.

But in the design of contemporary electronic information systems for use in work systems there is also another problem for sociotechnical systems design. As Dave Wastell and Sue White (Wastell and White, this issue) show in relation to child care services and Patrick Waterson (Waterson, this issue) shows in relation to health information systems, the aim of these technical systems is often to standardize task performance and to control how people work. These systems are often implemented to enforce a view of 'best practice' with the result that the people engaged in front-line work have great difficulty adapting their behaviour when the task they confront is at variance from the norm. Viewed from a forty year perspective we have a rather strange paradox: in 1970 when we started the HUSAT Research Group the only non-computer professionals using computers were people in work systems. Now everybody at home has computer-based products capable of multiple functions that they can adapt for their purposes in wondrous ways. But when they go to work the systems they use may seem light-years behind, limiting them to rule-following procedures that they cannot change. If, as predicted, we will live in a world of increasingly rapid change then we need work systems that can adapt and I interpret that to mean we need sociotechnical systems that enable human resources to learn and adapt individually and collectively. What is most frustrating is that, as Martin Maguire points out (Maguire, this issue), we have an increasing array of technical products at our disposal that make it possible to create technical systems that could be moulded to individual work needs and could be flexible as those work needs change. Martin Maguire illustrates, for example, how to address the software design issues in creating an offender management system so that it has interfaces to serve the diverse needs of the different users of the system. In a similar design vein Dave Wastell and Sue White (Wastell and White, this issue) describe the 'e-table' prototype system that uses computer technology in a way that helps social workers make sense of the bundle of different kinds of documents they may have about a child, a far cry from the current information systems that compress all this data into a standardized form.

My conclusion from reviewing the current state of sociotechnical systems theory and all the tools and techniques at our disposal is that we have a very good toolkit to help design the kind of work systems that will be needed in the future. The problem is getting the opportunity to use these methods and tools when these systems are being developed. And that raises the question of just how these systems are actually being designed.

4.5. The design process: on fragmentation and local design

The foundation premise on which many of us have worked for decades has been that the social and the technical sub-systems of a work system should be designed together so there can be overall system optimization. Whenever I speak about this people nod and say 'of course'. So why is it that, after all these years, there are so many examples of this not happening? Part of the answer is, I suspect, that technical people design technical systems and managers, human resources staff etc create social systems and they do not speak a shared language. However, the problem goes deeper than that because, in many situations, the sociotechnical system that does the work is the product of many different design processes spread out in time and space and, in reality, no one 'designs' the whole system. It may still be the case that when an entirely new work system is being implemented, e.g. in a new factory or process plant, that an integrated design process can be undertaken. However, in most of the implementations I have studied a better description of what happens is that, over a period of time, a succession of new sub-systems are introduced to an existing work system. Some of these implementations may be new technical systems, some may be re-organisations of the social system and they are often not connected to one another. In the UK NHS, for example, there is currently a major re-organisation underway which will bring in many new healthcare providers from the private sector at the same time as there are technical programmes to go 'paperless' and share electronic patient information. The technical developments are seeking system integration whilst the organisational developments signal more fragmentation. The description of 'ambient' organisations of the future provided by Niels Bjørn-Andersen and Benoit Raymond (Bjørn-Andersen and Raymond, this issue) suggests we will see many more fragmented work processes that cross organisational boundaries in the future. It seems likely that, for example, each social system in a supply chain will be the result of a different design process and that what binds the work process together are the technical systems they share and the contractual agreements the various parties sign.

But there are still more sources of fragmentation in the design processes that construct working sociotechnical systems. As Martin Maguire points out (Maguire, this issue) most of the software products used in work systems are purchased 'off the shelf', i.e. they have been created in R&D laboratories far removed from the work system in question and are available as mass market products. They frequently need customizing to perform the tasks necessary in a specific work process. They may also carry assumptions about the social system that will use the product that may not fit the reality of specific work processes. I have, for example, seen demonstrations of software systems to provide electronic support for meetings that presume each meeting will run strictly to the agenda predetermined by the chairman and at the end of each agenda item there will be a vote. I have attended very few meetings that conform to these assumptions.

The model of many sociotechnical systems developments that I have gradually been forced to recognize is then something like this. An existing work system is in a sufficient state of equilibrium to be able to undertake its daily operational tasks. It is subjected to a series of disturbances as new technical systems and new organisational changes are introduced. These new developments are largely fabricated somewhere else and are unlikely to be a perfect fit with the existing system. When the change is made there will be an implementation process that may involve some local design work to relate the new and old interdependencies in the system. In many cases disjunctions between the old and new systems only become apparent at a later stage and the workforce find ways of 'keeping the show on the road'. The resultant working system is thus a mixture of sub-systems designed in various places and at different times plus a leavening of ad hoc procedures introduced by the people charged with getting the work done. Any look into the future suggests that this pattern will become more prevalent and that the pace of the change episodes will quicken.

I have come to realize then that the opportunities to influence the single design process that creates a sociotechnical system of any complexity are getting fewer. The single design process is rarely there to influence. What then can we do? I have four suggestions that would implement many of the ideas presented above in a context of plural design processes:

4.5.1. Minimum critical specification of generic systems

When a sub-system, be it technical or organisational, is designed for implementation in many different work systems it needs to be designed leaving flexibility so that it can be customized to fit each local circumstance. One of the oldest principles in sociotechnical systems theory is that of 'minimum critical specification' (Cherns, 1976) which is broadly defined as don't fix in the system anything you don't need to fix. By all means, for example, have a voting option in the suite of functions in your electronic meeting support system but don't bind it into the normal usage procedure. Enable users to call it up when and if they want to use it.

4.5.2. Local design

Much of my work in the past twenty years has been helping teams in an existing work system accommodate a change process and I believe that this should continue to be the main focus of work to design sociotechnical systems. The local setting is the one in which the whole system has to come together; the technical system and the social system have to be aligned with one another in relation to the specific work process they are there to undertake. It is the point at which we have the greatest opportunity to design an integrated system. But, if the process begins by recruiting already designed technical systems and already planned organisational policies and processes, the local freedom for design may be very limited. In many cases the assumption is that the change will simply be 'rolled out' and there is no need for a local design process. It is that assumption that often leads to mismatches between the new technical system, the work to be done and the social system trying to do it. However, if the sub-systems recruited into an existing work system have been designed on the principle of minimum critical specification there should be scope to customize them so that the local sociotechnical system can be optimized.

One feature of local design that is becoming increasingly apparent is that the old assumption that 'local' meant within a particular organisation is no longer viable in many circumstances. Designing sociotechnical systems is all about the resources necessary to undertake the collective task and, as described above, this increasingly involves close collaboration across a number of organisations. In the health services this is known as 'middle out' design (Coiera, 2009) to distinguish it from 'top-down' design (which often ignores the differences between local circumstances) and 'bottom-up' design (which may optimize one part of the work system at the expense of other parts). These developments put a premium on careful analysis of where to place the boundary around any work system that is being designed.

4.5.3. User participation in local design

User participation and user-centred design have been our watchwords for many years and they are and will remain essential features of local sociotechnical systems design. It is the people in the current system who know the work process, have the knowledge and skills necessary to undertake the work and understand the social system, many parts of which may be implicit, that underpins the collective effort. One of the reasons for many technical system implementation disasters is that the design process has been dominated by a re-engineering of the work process to exploit the capabilities of increasingly sophisticated new technology. Dave Wastell calls this 'techomagic' (Wastell, 2011) and calls for local managers to play a much more active part in the development of new work systems. He concludes that they cannot afford to accept all the promises made by technologists and need to develop systems that support their staff in engaging in the real work. We can go further and say that the design of optimum sociotechnical systems needs those who understand the work process to be able to evaluate the undoubted promise of better technological tools and to be able to work out how best they can exploit them to support their work. Following Lisl Klein's (Klein, this issue) emphasis on making explicit the values that drive us in sociotechnical systems design, perhaps it is time to proclaim a new value: that human resources are not only the workers in the system, they must also be its designers. In my experience, when given this opportunity, many people feel unable to take up the challenge: they neither understand the new technical potential nor can they see how it might change their work for the better. Furthermore, they may not be able to see the ramifications of changes working their way through the rest of the work system. What is exciting is that we have many tools with which to work with users in pilots, demonstrations, scenarios etc to help them understand the potential and pitfalls of different ways forward and to put together combined sociotechnical systems that would make a real difference in their world.

4.5.4. Adaptation, user learning and system evolution

In a rapidly changing world no system put in place at a particular point in time is going to be well suited to the demands made on it for very long. It will need to adapt and evolve. This has a number of consequences for the continued effectiveness of sociotechnical systems. First, we have to re-affirm another of Albert Chern's principles and 'design for incompletion' (Cherns, 1976). This means that, when a system is implemented, it has to leave discretion for the people in the system to be able to develop new variants to cope with new circumstances and thus add to the repertoire of behaviours the system can exhibit. Local discretion must remain a cornerstone of job design and technical systems design must not only support normal work procedures but should be a flexible toolset that can be exploited to meet emergent needs.

But if all system adaptation is done at an individual level there is a danger that the system will grow in an uncoordinated way and changes in one place will have negative impacts elsewhere. So there is a second requirement that there are periodic reviews of the entire work system and further design efforts to configure it to meet new challenges. I shall call this the 'principle of continuous internal re-design' in order to emphasis three features of this process. First, it is driven by the internal reflections of the people in the system rather than, as is often the case now, by some external force demanding change. Second, it embraces the entire work system to ensure that all task interdependencies remain part of the review. And third, that it re-affirms the continuing role of the workforce as designers as well as doers.

There will, of course, also be occasions when outside influences demand a change in the work system, for example, when a new technical system is being rolled out across an organisation. If there is already in place a sociotechnical review process with engaged and knowledgeable users, there is a much greater chance that effective local design can be undertaken to assimilate external demands for change.

As described above and elsewhere in these papers we have many tools to support such a process: for example, summative evaluations to understand how well the system is performing its task and action research processes that will help people collect evidence about current system performance and link that to a re-design action programme. These processes that regularly reflect on 'how the system is doing' can be seen as the 'nuts and bolts' of building learning organisations and adaptive systems. If we keep in mind the goal of creating self-renewing sociotechnical systems and give the people in the system the tools to be their own designers we may be able to make major contributions to help people cope with the challenges of working in the future.

5. Conclusions

The papers in this issue span developments in sociotechnical systems theory and practice over a 50-year period. In that time the technologies available to support work processes have become very sophisticated and they play an increasingly important role in most work systems. In the 1960s many forecasters were predicting that we would soon have completely automated work processes; automated factories that would make products with no human intervention. If that had become the case we would have no need now of sociotechnical systems theory. But that has not been the outcome; instead we have collections of people engaged in complex tasks with and through sophisticated technologies. And there is every reason to believe that this will continue to be the pattern in the future. I noted at the beginning of this paper that the term sociotechnical was now in common currency and this may reflect a widespread understanding that we get most things done by using modern technology. I draw two conclusions from the inspirational work reported in these papers. First, that the design world is still very poor when it comes to creating social and technical systems that work together well to undertake complex tasks. Second, that we have many conceptual tools and design practices at our disposal that can improve the delivery of sociotechnical systems. There is every indication that, although the world of work is changing rapidly, these tools and practices will be of great value in meeting the challenges of the future. Perhaps the biggest challenge of all for sociotechnical systems practitioners is to find more opportunities to get involved in all the different design processes that create work systems.

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