E-infrastructures: How Do We Know and Understand Them: Strategic Ethnography and the Biography of Artefacts

Forthcoming in Computer Supported Cooperative Work

e-Infrastructures: How do we know and understand them? Strategic ethnography and the biography of artefacts

Neil Pollock and Robin Williams

Dr Neil Pollock, Reader, The University of Edinburgh Business School
Professor Robin Williams, Director, Institute for the Study of Science, Technology and Innovation
The University of Edinburgh

Address for correspondence

Professor Robin Williams
Director
Institute for the Study of Science, Technology and Innovation
The University of Edinburgh
High School Yards
Edinburgh EH1 1LZ
Tel: +44-131-650-6387
Fax: +44-131-650-6399
email: R.Williams@ed.ac.uk

Abstract

In health research and services, and in many other domains, we note the emergence of large-scale information systems intended for long-term use with multiple users and uses. These *e-infrastructures* are becoming more widespread and pervasive and, by enabling effective sharing of information and coordination of activities between diverse, dispersed groups, are expected to transform knowledge-based work. Social scientists have sought to analyse the significance of these systems and the processes by which they are created. Much current attention has been drawn to the often-problematic experience of those attempting to establish them. By contrast, this paper is inspired by concerns about the theoretical and methodological weakness of many studies of technology and work organisation – particularly the dominance of relatively short-term, often single site studies of technology implementation. These weaknesses are particularly acute in relation to the analysis of infrastructural technologies. We explore the relevance to such analysis of recent developments in what we call the *Biography of Artefacts* (BoA) perspective – which emphasises the value of *strategic ethnography* : theoretically-informed, multi-site and longitudinal studies:. We seek to draw insights here from a programme of empirical research into the long-term evolution of corporate e-infrastructures (reflected in current Enterprise Resource Planning systems) and review some new conceptual tools arising from recent research into e-Infrastructures (e-Is). These are particularly relevant to

understanding the current and ongoing difficulties encountered in attempts to develop large-scale Health Infrastructures.

Key Words

e-infrastructures; biography of artefacts (BoA) approach; strategic ethnography; enterprise resource planning (ERP) systems; health infrastructures;

1. Introduction

Various writers have drawn attention to the increasing scope and scale of information systems (focusing particularly on their longevity, ever wider application and implications for various kinds of work). The facility that these systems offer for sharing information across the boundaries between occupational and organisational groups has been seen as transforming scientific research and knowledge-based work and services more generally. The concept of 'infrastructure' has been applied to the structures of codified information (Star and Ruhleder 1996), and *qua* information infrastructure also to the hardware, networks and software systems via which they are increasingly stored and accessed (Monteiro and Hanseth, 1995, Hanseth et al. 1996). The application to scientific research of powerful new computer-based tools such as 'the Grid' (in such areas as Translational research and genetic health databases) has been associated with the term e-infrastructure, e-Research or e-Science, or in the USA cyberinfrastructure (Edwards et al. 2009).[i] The need for such systems to cater for a wide range of current users and uses (and, given their development costs and intended longevity, potential future users and uses) makes their design and further evolution potentially challenging.

Social scientists have been drawn to address the emergence, use and evolution of these systems – particularly in the areas of health research and health service delivery, where enormous investments have been made in the last decade, but where acute problems have also been encountered in both development and maintenance. This paper questions whether or not scholars have adequate social scientific tools for getting to grips with e-Infrastructures. It argues that we need more elaborate methodological templates and conceptual frameworks for analysing both the dynamics and the constraints surrounding these developments, for characterising the problems and factors that underpin them, and identifying how these problems may be ameliorated such that we can guide policy and practice.

The starting point for this paper is our dissatisfaction with some of the dominant analytical traditions on technology and work organisation, where we have identified shortcomings that are particularly relevant to enquiries into e-infrastructures. We have begun to develop the Biography of Artefacts (BoA) perspective to redress these theoretical and methodological weaknesses and provide more effective analytical templates to guide research and perhaps intervention.

2. Some shortcomings of existing research into technology and work organisation

Research into technology and work organisation has suffered from the fragmentation of enquiry between various disciplines and schools of analysis - with their differing foci and concerns - and which have tended to be associated with different kinds of study. We draw attention particularly to the divide between a relatively small cohort of researchers (mainly from Science and Technology Studies [STS] but also from Information Systems etc.) who have undertaken studies that encompass technology design and development (MacKay et al. 2000) and a much larger group which has focussed more narrowly on their organisational implementation and use. Here we find a substantial body of work

informed by diverse perspectives within Management Schools - including Organisation Studies, Technology Management and Strategic Management - as well as Information Systems Research and Science and Technology Studies and what we may describe as socially-oriented computer-science, including Social Informatics and Computer Supported Cooperative Work (CSCW). Studies of organisational adoption constitute the overwhelming bulk of contemporary research into enterprise systems and other organisational technologies (ERP Research Group 2006; Pollock and Williams 2009); only a very small number of studies (largely from Science and Technology Studies) address technology design and use in tandem (MacKay et al. 2000, Williams et al. 2005, Hyysalo 2010).

We also note the theoretical and methodological weakness of much of this research, arguably reflecting the dearth of rigorous and critical social science analysis where much of this research is undertaken (predominantly the Business School). Much of this work thus suffers from a lack of an adequate analytical framework coupled with the unreflexive adoption of rather simplistic methodologies - shortcomings that have been subject to longstanding critiques of empiricism within social sciences (Williams and Edge 1996). Linked to this we note the predominance of short-term studies of technology adoption and in particular of company case-studies.

We contend that there has been a failure within much research into technology and work to reflect upon how the choice of particular analytical framings, methodologies, tools and research design may tend to highlight certain kinds of finding. For example the separation between studies of technology design/development and of technology implementation/use is reflected in the circulation within many implementation studies of stereotypical accounts of technology suppliers from the perspective of the organisational user often in the early stages of implementation (e.g. stories of supplier offerings "thrown over the wall" to unhappy organisational users). Such experiences are important – they flag the gulf between necessarily generic supplier offerings and the specific practices of organisational users, and the work that must be done to adapt a new complex technology to their purposes and practices. However this kind of account simply fails to do justice to the complex promotional and design/development strategies of successful vendors. In the next section we examine the consequences for research findings of the prevalence of the kinds of short-term studies of technology adoption that we characterise as 'impact studies' and 'implementation studies'.

We are, of course, more than happy to acknowledge that there have also been important contributions from studies of technology implementation, and in particular from the vibrant body of more critical and analytically sophisticated work arising particularly from what we may describe as interactionist and constructivist studies within Business Studies, Information Systems Research, Social Informatics, Science and Technology Studies, CSCW and so on. This work has, for example, offered a better understanding of the relationship between technological change and workplace activity, highlighting in particular the intricate sociotechnical processes whereby work activities such as information exchange and task coordination are achieved (Luff et al 2000). We recognise their valuable critique of mainstream functionalist and normative approaches within Management and Systems Development thinking. However we have reservations about their epistemology and consequent methodological choices. In particular, we note the dominance of 'single site ethnographies' (typically studies of technology implementation) and, given the limitations of research access and funding, their limited duration.

In articulating relevant aspects of the BoA perspective below, our work seeks instead to expand the focus of research longitudinally and across different social settings and scales, addressing multiple moments and sites of innovation, and encompassing different phases

of what has been described as the systems development cycle (design, selection/ procurement, implementation and use), and the multiple such cycles that constitute the product cycle for a particular artefact.

2.1 Impact studies

One of the first kinds of paper to emerge when a new technology is launched is what we term the 'impact study'. We find articles appearing first in the practitioner and trade journals oriented towards potential adopters. Their message is in general rather simple – geared towards the questions a potential adopter might ask: what is this technology and how can it benefit my business? Typically these are presented as a 'before and after' study, with a narrative of improvement, starting with the problems the organisation was encountering; the identification of a new technology that offered a solution, its adoption and of the benefits delivered (see for example Botta-Genoulaz et al. [2005]). These accounts are often linked to the suppliers and consultants involved; and they had a tendency to uncritically reproduce supplier claims (Webster 1990, Fleck et al 1990). This was especially notable in the opening stages of the widespread historical adoption of IT within organisations when visions and promises of the benefits of new technologies were confidently articulated in advance of the often much more mixed experiences of their adoption and use. Latterly, experienced journalists and commentators have tended towards a more sceptical voice (why choose this technology amongst so many other contenders?). The case-study of new technology adoption and its successful outcomes seem to provide an important currency for validating technology to potential organisational adopters (Graham et al. 2003, Pollock and Williams 2009). However, this kind of writing often lacks analytical distance or critical concerns. Implicitly, through their 'before and after' framing, as well as the result of any commitments of the writers, these papers often articulate an engineering or managerialist view of technology as instrumentally transforming work.

2.2 Implementation studies

The next wave of papers arising from practitioner and academic circles largely comprises what we describe as 'implementation studies'. These have a stronger empirical base than the impact studies, though, like the latter, they are often undertaken in the immediate aftermath of technology adoption. Such studies frequently highlight the gap between the expectations that surrounded a new technology and it immediate outcomes (for reviews of this literature in relation to Enterprise Resource Planning systems [ERP] see Esteves and Pastor [2001] and Al-Mashari [2003])[ii]. This work does engage critically with supplier claims. Issues remain about how to interpret the longer-term significance of these findings. By emphasising the obstacles to technology-induced change there is risk of replacing the CAN DO messages of technology promoters with a NO CAN DO analysis and of conflating the immediate and longer term outcomes of new technology implementation (Williams 1997). This may produce an incomplete and misleading understanding of the consequences of technological change – consequences that may only become clear after years or decades.

Implementation studies are typically medium-term studies starting in the course of, or shortly after, the introduction of a new technology. There is thus a temporal framing – both upstream and downstream of the implementation process. The upstream framing concerns the difficulty of researching directly the 'pre-project' phase in which particular problems and the possibility of technical solutions are articulated together. The decision to adopt thus typically becomes a taken for granted feature, addressed only in hindsight – a hindsight view in which many uncertainties and shifts in perception may be suppressed by the desire to legitimate a decision already taken (McLaughlin et al. 1999, Gerst 2006).

The fact of adoption (or at least a decision to adopt) is what has driven the selection of the cases for research. These prior 'pre-project' decisions also frame the way in which the implementation study is undertaken insofar as a number of decisions have been taken about the scope of the new technology project (including for example defining the problem to be addressed and the resort to technical solutions). In this process, we note the establishment of particular sociotechnical configurations (Sahay et al. 2009) - emerging as a result of initial interactions amongst the complex arrays of actors potentially involved in the project – which constitute what we have described as the 'translation terrain' (Williams et al. 2005).

The downstream framing arises from the limited duration of many studies, typically to periods of a few months or at most a couple of years. However a body of research going back to the work of Arrow (1962) points to protracted processes of 'learning by doing' through which the efficiency and other benefits of a technology are improved by trial and error experimentation. Fleck (1988:3) takes this idea further with his notion of 'innofusion' which highlights the way in which artefacts, rather than being fixed at the design stage, are transformed in their implementation and use, in the course of "the struggle to get the technology to work in useful ways at the point of application". Similar processes have been identified by other writers, using slightly differing conceptualisations described variously as appropriation (MacKay and Gillespie 1992), domestication (Sørensen 1996) and social learning (Sørensen 1996, Williams et al. 2005).

Research investigating the organisational implications of Enterprise Resource Planning (ERP) systems immediately drew attention to the implementation difficulties encountered with these complex software systems and the potential for failure. These difficulties were attributed to the 'misfit' between the standardised presumptions embodied in the packaged solutions and the specificity of user organisation practices and the consequent need either for expensive customisation or unwanted organisational adaptation (Soh et al. 2000, van Fenema et al. 2007). Many writers concluded from these experiences that ERP was expensive and undesirable. Such dismissive accounts leave us with a problem, however: how can we to explain the wide adoption of ERP across many different kinds of organisation worldwide? A later body of work argued that the benefits of ERP do not appear for a number of years (Mabert et al. 2001). It was therefore necessary, they suggested, to extend the timeframe of research into the 'post-implementation' phase also described as the 'onward and upward' phase (Somers and Nelson 2004, Wei et al. 2005, Wu 2008). Elsewhere, echoing some of the sentiments of this latter work, we have drawn attention to the enormous effort involved in bridging generic supplier offerings to specific organisational settings through intertwined processes of *innofusion* - in adapting these complex information systems to particular organisational settings and of *domestication* - as organisations learn to exploit the affordances of complex technologies in redeveloping their information and work practices (Pollock & Williams 2009).

2.3 Design oriented studies

An important stream of studies of workplace settings has been directed towards improving the design of computer-based systems. Much of this work has emerged from the socially-oriented computing perspective (including, for example, Social Informatics and CSCW). This work has emphasised the double value of workplace ethnographies, *directly* as a source of detailed empirical information about particular organisations, activities that can be a resource for system design and also *more generally* as a way of achieving a more adequate understanding of how work is constituted and achieved. The rich empirical picture of workplace activities that can be achieved by ethnographic research is envisaged as helping overcome the difficulties encountered with traditional

methods of 'requirements capture' that only engage with the formal descriptions of how work tasks are supposed to be undertaken. By drawing attention to the range of informal procedures through which work goals are carried out, including dealing with frequent 'abnormal instances', such studies were seen as providing the information required for designing tools and systems that could better support the ways in which work activities are actually performed (Plowman et. al. 1995, Luff et al. 2000). However this goal has proved somewhat elusive for a number of reasons (Ackerman 2000, Schmidt 2000, Stewart and Williams 2005). In particular, those involved in design stressed the difficulties of packaging sociological understandings into a form that could inform workplace analysis and design (Dourish 2001, Fitzpatrick 2003). The social scientists involved conversely raised two sets of questions. The first revolved around what kind of empirical investigation was needed to acquire an adequate understanding of work settings. The developers' need for timely information about potential users and uses, and the prohibitively high costs of protracted labour intensive ethnographic research, prompted suggestions for the adoption of 'quick and dirty' ethnographies, which could yield information better targeted to designers' needs and in more manageable volumes (Hughes et al. 1994, Anderson 2000, Martin and Sommerville 2006). Such methods were however widely criticised as potentially generating misleadingly simplified accounts of the social settings being studied compared to the more robust understandings available from extended ethnography.[iii] The second set of questions concerned the role and responsibility of social scientists. Social scientists observed that the knowledge they generated could not simply be packaged into a form which others could use. Moreover, sociologists and anthropologists were generally unhappy about being cast into an instrumental role of providing information which others (designers, managers) would use (and might abuse!). They sought instead to retain some accountability and control over how their findings would be utilised. Rather than aligning with managerial or developer objectives they saw the need to make their interventions accountable to various stakeholders – including the various groups of workers who might be affected by a new development (Suchman 2002). Difficulties in determining how their knowledge would be applied, and also in developing effective communications with design specialists led some to suggest that the gap between organisation members, ethnographers and design specialists should be collapsed in a process of 'co-realisation' (Hartswood et al. 2002, Voss 2006).

2.4 The link between types of study and research findings

This brief review has given some illustrations for our suggestion that particular types of study are closely associated with certain kinds of findings. This association is not intentional – indeed it has gone almost totally unrecognised by scholars who will typically be involved almost exclusively in one or other type of study and with their particular research perspective (Law 2004). It may be no coincidence that the insights we report here come to the fore as we reflect upon an extended programme of research that has occupied us over two decades.

At the outset of this period, one of the authors conducted a set of case-studies of new technology adoption in the workplace. This included two firms in the same area (the West Midlands in the UK) adopting the same technology (Computer Numerical Control Machine tools) to produce similar products (aerospace components) but with radically differing forms of work organisation (operator programming versus technician programming) (Williams and Steward 1985). These kinds of short–term case-study comparisons, perhaps inevitably, draw attention to the scope for variability between cases and thus for *choice* (Bessant 1983) surrounding technology and work organisation,

shaped by local contingency including the micropolitical strategies of organisation players.

In contrast historical studies of technology and work, comparing workplaces over a long timeframe – perhaps contrasting these workplaces studied in the 1980s with their counterparts today - would immediately draw the observer's attention to the substantial concerted changes over time in how work is done. We would be struck by similarities in, say, office or factory work settings today and striking differences from their counterparts 20 years previously. Social scientists seeking to explain these concerted changes might be drawn to look for institutionalist explanations (for example in terms of what DiMaggio and Powell [1983] describe as isomorphic pressures due to the influence of prevalent managerial programmes or technologies [Tingling & Parent 2002]), the globalisation of the economy and the influence of technological change.

2.5 Narrative bias

Particular kinds of study have characteristic framings, it transpires, in terms of the duration of study, in the trade off between breadth and depth of empirical enquiry, and in the temporal and societal boundaries around what is addressed. In addition the various schools of analysis and types of study seem also to be associated with certain narrative repertoires. What makes a 'good study' is linked to its ability to touch upon the core concerns of a school of enquiry including ideas about the key problems needing to be addressed and possible solutions. We have used the concept of *narrative bias* to invite more reflection upon how particular schools of analysis often come with classic stories attached; they are associated with dramatic repertoires; heroes and pitfalls, problem diagnoses, dilemmas and solutions (Stewart and Williams 2005). Consider, for example, the contrasting narrative structures and concerns of two important strands of analysis within STS which are of central relevance to understanding the emergence of certain kinds of expert knowledge and technological infrastructures. These are the Sociology of Classification and studies of the socioeconomic shaping of inter-operability standards.

The Sociology of Classification (as exemplified by Star and Ruhleder [1996] and Bowker and Star [1999]) emphasises the ability of new classification systems to impose order and in this way to prioritise one world view over others (Timmermans and Berg 1997, Berg and Timmermans 2000, Hardstone et al. 2006)). In contrast, socioeconomic studies of the development, adoption and implications of the interoperability standards which are at the heart of the emergence of Inter-Organisational Network Systems and other e-infrastructures emphasise the difficulties of achieving common standards – in terms both of reconciling the competing needs of different stakeholders in initially agreeing standards and, once particular local (regional or sectoral) standards have been implemented, the difficulties of migrating towards later generic standards (Graham et al. 1995, Graham et al. 1996, Williams 1997, Ciborra et al. 2001). These traditions have each theorised, and, perhaps unconsciously, given particular emphasis to one aspect of infrastructures. We argue that an adequate account needs to develop a balanced theorisation that for example addresses both the immediate barriers to standardisation efforts and the possibility and significance of such alignments (Timmermans and Berg 1997, Williams 1997, Hardstone et al. 2006). Moreover, these necessarily incomplete alignments of meaning and practice, can become 'infrastructural', crystallised into standards and classifications, embedded in software and organisational routines) and can in turn become components in the further innovation of practices and systems developments (as Berg and Timmermans [2000] have noted in relation to systems geared towards health professional work).

3. The need for new kinds of research perspective

Our broader thesis here is that various critical engagements with what we may call 'the modernist project' have produced a pattern of dichotomised debates and partial accounts. One of the most influential here has been the 'localist' and 'interactionist' turn, which has emerged in reaction against 'universalist' claims that powerful new technical capabilities provide solutions that can readily be applied and bring improvements in many diverse organisations in different sectoral and regional settings, and across different departmental structures and work groups. We note the growth of ethnographic accounts of technology in the workplace, inspired by ethnomethodology (Button 1993) and in particular by the influential work of Suchman (1987). These 'interactionist accounts', which attend to how social relationships are constituted and maintained through social interaction, emphasise the improvisatory role of local actors in sustaining organisational practices. The consequent diversity of work practices and uniqueness of organisational settings mean that standardised technical solutions often fail or can only succeed as a result of the active repair and workarounds by users (see Pollock 2005). These issues have been primarily addressed through rich ethnographic studies, often of particular places of work. Such research has provided an inspiring and rich intellectual context for our research. However we are becoming frustrated with their embedded epistemologies and characteristic research designs (Pollock & Williams 2009). Their privileging of the local is frustrating, particularly in a context of increasingly pervasive information system adoption which mean that local interactions are increasingly bound up with technology development processes and organisational practices elsewhere (Suchman 2002, Kallinikos 2004, Ellingsen and Monteiro 2006). We have, in addition, had long-term reservations about the limited ability of such research (that typically involves short-term ethnographic case-studies of particular work groups or organisations) to theorise longer-term processes and the influence of the broader historical and institutional context which pattern and structure these local processes (Williams and Edge 1996). The question this paper seeks to pose is whether we can go beyond these simple analytical lenses to generate richer and more effective accounts of complex sociotechnical phenomena such as the evolution of e-infrastructures?

3.1 A framework for addressing the evolution of e-infrastructures

To this end we need an analytical framework that can account for both stability and change in sociotechnical relations and how these can be addressed over different time spans. Thus we need concepts that can encompass both:

- the short-term dynamics surrounding the selection, implementation and embedding of new technologies encompassing incremental changes and also the continuity of existing social relations. Here, Webster (1990) has observed that where there was a collision between existing work practices and the presumptions built-in to technology, it is the former which often seem to be more immediately durable, and
- the longer-term evolution of work practices and technologies in which we may simultaneously see both:
  i) gradual alignment around generic and specific standards, technical infrastructures and other crystallised social relations; and,
  ii) new dynamism and differentiation.

The Biography of Artefacts (BoA) perspective (Pollock and Williams 2009, Hyysalo 2010) emerges from our attempts, with others, to undertake such an analysis in relation to one of the most successful current organisational e-infrastructures – the ERP systems which have become widely adopted in private and public sector organisations.

4 The Biography of Artefacts (BoA) perspective

The BoA perspective emerged in the course of protracted efforts amongst a small community of scholars to produce a deeper theoretical and empirical account of the relationship between technology and organisation. Our early research had demonstrated the need to move beyond episodic (short-term single site) studies of settings of technology design or its organisational implementation/use and instead to address the evolution of workplace technologies over multiple cycles of design and implementation. Brady et al. (1992) suggested that packaged software artefacts had biographies – highlighting how bespoke applications were sold-on to other firms in the same (financial services) sector and formed the basis for commodified solutions. Building on earlier research which showed that new workplace technologies often emerged through the enhancement of existing applications (Fleck et al.1990), Williams (1997a) further applied the concept of biographies to analysing the historical evolution of integrated information systems like Computer-Aided Production Management (CAPM). When supplier offerings were implemented, they inevitably had to be adapted to fit the technical and operational circumstances of adopting organisations. This process often threw up further useful innovations that could feed into future technology supply. Workplace technologies thus evolved through successive cycles of technical development and industrial implementation and use, a 'spiral of innovation', oscillating between moments of development, implementation and use. These short-term cycles were phases in a longer-term biography; and longitudinal studies showed how the CAPM and Manufacturing Resource Planning (MRP II) systems of the 1980s and 1990s, widely seen as the precursors for today's ERP systems, themselves emerged from stock and production control systems developed in the 1960s in vehicle and aerospace sectors (Fleck et al.1990).

4.1 Research designs to capture biographies of infrastructural artefacts

Following on from this, a number of studies explored the subsequent emergence of ERP and its wide uptake. These provided a rich conceptual and empirical base for articulating and testing the BoA perspective (see for example Clausen and Williams 1997). In developing this perspective we sought to exploit the richness of ethnographic study and its open-ness to contingency in processes and outcomes. However we also wanted to redress weaknesses of the naïve research designs frequently adopted under the dominant action-centred traditions (for example, the relatively short-term, single site ethnographies favoured by many interactionist analysts). [iv]

Our articulation of the BoA perspective reflects our concern to engage more coherently with the ways in which longer term history and the broader context shape innovation processes and outcomes. Koch (2003, 2007) pointed out that we should move away from a focus on particular innovation moments, organisations and artefacts, and perhaps think of complex organisational technologies like ERP systems as a 'community', embracing user organisations and other intermediaries as well as suppliers, and as 'heterogeneous assemblages' encompassing software artefacts, suppliers, organisational users, consultants, work practices and visions of organisational improvement.

4.2 The need for strategic ethnography

Very different kinds of research design are needed to address this. We have proposed (Pollock and Williams 2009) what we describe as 'strategic ethnography' – whereby the choice of research settings and the scope of studies is informed by provisional theoretical/empirical understandings of the locales in which new technologies are being shaped[v] as well as by the specific research concerns and issues under examination

(though we note that research design choices are also necessarily influenced by opportunism and pragmatic exigencies). Thus we concur with proposals for multi-sited ethnography to provide more robust, contexted understandings of complex objects (Marcus 1995, Hine 2007). In relation to technological change we propose that research should engage with the multiple locales and moments of innovation (encompassing, for example, technology design, procurement, implementation, maintenance) (see also Kallinikos 2004).

In contrast to the short-termism of much research (conditioned by the typical duration of research project funding), studies need to tackle extended timeframes, through more complex temporal designs including longitudinal studies, follow-up studies and long-term historical investigations. Working specifically with various health ICTs, Hyysalo's (2004, 2010) work has offered a more systematic theorisation of the multiple histories that intersect in every episode in the biography of an artefact. His framework (building upon Hutchins 1995) ranges from the short timeframes of conducting particular tasks to the long-timeframes of the development of wider institutional practices. In our work we approached this challenge in a number of ways. These included studying mature products and those at an early stage in their product lifecycle; combining historical and contemporary study; and, by undertaking several research projects over a period of more than 10 years. These multiple temporalities equally encompass both immediate contexts of interaction and the more generalised contexts in which innovation unfolds. Here we have focused upon the emergence and evolution of technological fields, through interactions between suppliers, organisational users and various kinds of experts and consultants (and especially noting the emergence of organisations such as the industry analyst Gartner that have come to play a key role in drawing boundaries around and distinctions within technological fields like ERP [Pollock and Williams 2007]).

These research design considerations suggest a radical rethinking of the model of how research should be designed and undertaken. Detailed studies of particular innovation moments (e.g. of design/development, implementation/use, post-implementation support), though valuable, need to be supplemented by studies at the interstices between organisations (e.g. of marketing/procurement and the construction of markets). Research needs to be extended spatially to see how technological fields and markets are constituted and organised as well as temporally to address the longer term evolution of the technology and its associated organisational practices (e.g. including further implementations and feedback into future technology supply and the extension of a product into other markets). This is no small feat. An effective account of the biography of an artefact perhaps needs to be a team project at least and perhaps seen as the outcome of a research programme amongst a community of enquiry. We can explore these issues through our case study of the evolution of ERP systems and their precursors (Pollock and Williams 2009).

5. The Biography of Enterprise Resource Planning (ERP) systems

5.1 Packaged enterprise systems - an impossible project?

Most of the top UK, European and US corporations and a growing range of public sector organisations have adopted packaged ERP systems. Sold for example by firms such as SAP, these are integrated solutions which handle a vast array of different kinds of transactions right across the organisation. Their success presents something of a challenge to the dominant analytical fashion across a range of traditions (including socially-oriented Computer Science, CSCW, Information Systems Research, Technology

and Organisation Studies) which, as already noted, informed by ethnomethodological and interactionist accounts, share an emphasis upon:

- the uniqueness of particular organisational settings and practices (Hartswood et al. 2002);
- the consequent gulf between standard generic enterprise software solutions and these practices (Soh et al. 2000, Walsham 2004, Taylor and Virgili 2008).

Packaged ERP implementation is accordingly often portrayed in these accounts as risky and imposing high costs (as well as the high purchase price for these enormously complex software systems, costs include the significant expense and effort of adapting software to user needs or of adopting unwanted organisational change to align to the templates built-in to the packaged solutions) and uncertain in its benefits.

Arguably the frameworks adopted in the bulk of the literature are thus not well-equipped to explain the phenomenal success of standardised ERP solutions. The success of the ERP suppliers did not, however, correspond to the modernist dream of a new e-infrastructure conceived as a universal solution that can somehow anticipate and cater for the entire range of organisational contexts and practices. We have shown that SAP (and other ERP package suppliers) did *conquer the world*. However ERP's success was achieved through an arduous process of selectively accommodating and sorting user requirements in close relationship with existing and prospective organisational users to produce generic solutions for market segments. And ERP expanded into other markets one segment at a time, through the gradual extension of their offerings from the manufacturing sector to chemicals, financial services, and latterly public services etc.. This process of building product markets and extending into other segments was characterised by frequent setbacks failures and reversals as the supplier grappled with difficult and contradictory contingencies. Our work explored the detailed techniques and strategies developed by vendors to manage these tensions and their attendant trade-offs (Pollock & Williams 2009).

5.2 Mapping the biography of artefacts

We were, for example, able to document and explain the extension of packaged enterprise solutions through a series of historical and contemporary ethnographic studies that addressed different moments in the life-cycle of an ERP package (technology design, procurement, implementation, maintenance). Thus we were able to explore how, in their design and development decisions, suppliers of standard ERP packages were able to build viable 'bridges' to diverse organisational users by various kinds of 'generification work' (Pollock et al. 2007). Generification involved a complex set of interactions and alignment efforts between the developer and its user community. Our studies revealed a number of linked strategies deployed by suppliers to manage this process including segmenting the market, enrolling selected user organisations as development sites and as members of 'user groups', and subsequently by sorting, aligning and prioritising user requirements. For example, when a major ERP supplier moved into the Higher Education sector, we saw how certain organisational users sought to gain influence over the development of the package by establishing themselves as pilot sites. We also observed how a major University (Big Civic) experienced a certain loss of control as the supplier expanded the array of pilot users around which it was developing its products. Later the supplier enlisted members of its user community to help them identify homologies of practice that would be implemented in their new product. This was not so much a search for identical ways of doing things between their different customers but was an attempt to establish limited spreads of practice that could be handled in similar ways by their necessarily generic software package. Through what we described as

'process alignment' work they established equivalences between disparate organisations around a manageable level of diversity which their package would cater for in its generic functionality. Other kinds of requirement were in contrast rejected as 'organisationally specific'. These design choices reflected the operation of a complex 'political economy' as the supplier established boundaries around the market for its product and segmented the market. Thus, product enhancement proposals were assessed against the standing of the customer, its representativeness and importance. Equally the supplier selected organisations as pilot sites on the grounds of their size, reputation and salience in the sector and their willingness to invest in the pilot implementation and thus their potential as visible exemplars to others in sector. There was a hierarchy of users . At the other end of the spectrum, were the "transactional users" which the supplier treated on a more strictly commodified basis – offering to install additional functionality only if they paid for it. Our study revealed the array of techniques that suppliers had developed to manage this process – to align and organise its relationship with their user markets and achieve effective closure around product features.

A parallel study explored the homologous challenges faced by a software supplier at a much earlier stage in the product cycle. The newly established supplier seeking to convert its new organisational software into a packaged solution had to reconcile escalating levels of customer diversity as it sold its product on to other organisations with differing needs and practices. Its initial strategy of 'accumulating functionality' to cater for the additional requirements of each new customer rapidly gave way to an attempt to sort and regulate these requirements in order to keep the product development and maintenance process manageable.

These generification strategies do not constitute universal principles for the design of software solutions.[vi] Instead they represent the lessons learnt by suppliers and the techniques they developed to manage a set of broadly homologous trade-offs with which probably confront all suppliers of complex packaged solutions. Crucially, these dilemmas change over the product life cycle – in the early stages as an application was recycled to other organisational users and developed as a packaged solution, and again when a packaged product designed for one environment was re-worked to allow it to travel to other sectors and segments.

We have also been able to chart, through this and previous studies, the historical roots and evolution of ERP. These could be traced directly back to 1960s stock control systems and 1970s Materials Requirements Planning (MRP) systems, and their progressive extension to Manufacturing Resource Planning (MRP II) systems in the 1980s, through (in some accounts) Computer Aided Production Management in the late 1980s, to the 1990s emergence of ERP. Reflecting upon this longer-term history also draws our attention to the changing fabric of the sociotechnical terrain. Thus MRP emerged from discussion amongst production managers about optimising work scheduling – who initially developed their own applications. Later these become bound up with packaged software solutions with extended functionality across the whole organisation (Clark and Staunton 1989, Webster 1991). And whilst accounts of these early stages stress the role of key individuals involved – the 'three gurus': George Plossl, Joe Orlicky and Ollie Wight – the final stages of the story are populated by a web of various kinds of organisation as the field becomes more institutionalised – not just managers in user organisations but also software suppliers, consultants and industry analysts who help shape and guide users through the ERP market. To address these we need analytical tools that can encompass this changing register and the relative salience of different kinds of individual or collective action across different periods and contexts, rather than from the outset privilege action or structure.

6. Towards a Biography of e-infrastructures?

6.1 What can we learn from looking at different (e)infrastructures?

We have elaborated our BoA framework through studies over recent decades charting the unfolding of ERP and some other major organisational technologies at multiple sites of design, procurement and implementation. Our findings have been supplemented by those of an informal community of researchers also active in these areas (see for example, Clausen and Williams 1997) and united by a common interest in 'the Social Shaping of Technology' (MacKenzie and Wajcman 1985, Williams and Edge 1996). Our goal was to provide an approach that could be relevant to other long-lived complex technologies. The framework seems particularly relevant for addressing the emergence and evolution of technology infrastructures.

Indeed ERP is arguably an e-Infrastructure. Though in much of the literature, the design and implementation of ERP has been analysed as an organisational *IT application*, Hanseth and Braa (1998) suggested that ERP should instead be analysed as an organisational *Information Infrastructure*, noting that it is subject to the same dilemmas, for example over alignment of multiple stakeholders over extended periods, that such infrastructures face (Monteiro and Hanseth 1995, Hanseth and Braa 1998, Ciborra et al 2001). ERP is often implemented across multiple sites within large branch-plant organisational structures (Markus et al. 2000, van Fenema et al. 2007). Indeed one reason cited for the early success of SAP's R/2 system was its wide adoption by European multinationals, which valued its ability to handle multiple currencies and languages (Pollock and Williams 2009). The success of packaged enterprise solutions may in part reside in the way they provide a template for the corporate Information Infrastructure, offering a solution to otherwise intractable issues of system standardisation and information harmonisation across multi-branch enterprises. In this sense ERP can be seen to provide an architecture for intra-organisational communication across large heterogeneous organisations, as well as specific application solutions. In addition, Kallinikos (2004a) notes that ERP packages reproduce and reinforce prevalent corporate organisation structures. As a result, ERP and its embedded business processes and presumptions become taken for granted. This discussion strongly parallels discussions in the sociology of classification of how particular categories become infrastructural (Star and Ruhleder 1996).

Our own work has also noted the convergence between two hitherto somewhat separate technology trajectories concerned, respectively with intra-organisational integration (underpinning today's enterprise systems) and inter-organisational information networks and systems. Our studies observed the extension of ERP to support inter-organisational exchange (e.g. through Customer Relationship Management systems). With the growth of e-Business technologies, whereby organisations collaborate on procurement and supply-chain integrations (Gerst 2006), ERP systems are now coming to be seen as parts, albeit large components, of wider e-Infrastructures.

Our interest in organisational e-Is has brought us into contact with colleagues with parallel interests in the USA. Research workshops organised simultaneously in Edinburgh and Michigan both sought to explore whether lessons could be drawn from looking at various existing kinds of physical and information infrastructures for currently emerging e-infrastructures.[vii] This resulted eventually in a jointly edited special edition of the *Journal of the Association of Information Systems* on *e-infrastructures* (Edwards et al. 2009).

As Monteiro and Hanseth (1995) point out, (information) infrastructures differ one from another. Analysis must attend to their specific technical and organisational features. Some of the factors that led us to develop the BoA perspective (in the case of organisational technologies) are particularly relevant to emerging e-infrastructures (e-Is). They are large-scale pervasive initiatives that must accommodate a large number and diverse range of users and uses. Linked to this, substantial investments must be made in their development – and (in order to secure the benefits in this investment) in their subsequent maintenance and enhancement. They thus emerge and evolve over long timeframes. And their development and redevelopment must consequently find ways to cater for users and uses not currently anticipated.

These features – which underpin our decision to describe them as e-infrastructures rather than as computer systems (Edwards et al. 2009) - throw up a number of theoretical and practical issues. To address these, we propose a programme of research to explicate 'the biographies of e-infrastructures'. The BoA perspective suggests the advantages of multi-local and multi-temporal studies. However the need for multi-local analysis is not just a question of addressing an ever greater number of sites. Rather it is a question of which locales and moments to address. We need instead specific sensitising concepts to guide both the empirical research design and its analysis. But do we have a set of specific concepts for analysing e-Is, beyond these somewhat generic constructs?

7. Some recent concepts for analysing e-Infrastructures

Recent social scientific research on e-Is provides some important pointers (and here we draw particularly on the *JAIS* special edition on e-Is [Edwards et al. 2009]). Though not specifically informed by the BoA perspective this work provides valuable examples of the kind of analysis needed to create a biography of e-Is and, more importantly, throws up valuable novel ways of conceptualising these biographies.

e-Is exhibit some common features with computerised systems in general. For example, with integrated organisational applications, issues arise regarding the alignment of differing departments and functional groups within the organisation. In addition to the consequent need to accommodate potentially diverging 'user requirements' across different parts of the organisation, we note the need to reconcile current and emergent uses and users (Williams et al. 2005, Johannessen and Ellingsen 2009).

At the same time there are also some distinctive features of e-Is which underpin our decision to distinguish them from conventional information systems. These include the particularly large-scale of e-Is and their (intended) longevity. Scale here is a question of both the number of users and the range of users/uses. This means that they cannot typically be developed or procured as integrated solutions but require extended periods of investment for their initial development/procurement and subsequent enhancement and evolution. In recognition of this, Edwards et al. (2007) suggest that it may be more helpful to apply a metaphor of *growing* rather than designing or building e-Is. These features mean that e-Is result from large-scale, protracted investments, and tend also to have very long timescales. They are typically erected on the foundations of earlier systems development and implementation work (Chae and Poole 2005). Edwards et al. (2007) have described how earlier, more small-scale/localised e-Is come into contact with others based around different purposes, standards or classification systems. Difficulties in aligning the entrenched differences between these local systems generate pressures of competition or accommodation between systems that may be resolved through the creation of *gateways,* which allow multiple divergent systems to interoperate. The tensions and discrepancies between these local systems may in due course generate

pressures leading to periodic adjustments and redevelopments to accommodate changing internal and external circumstances (Ribes & Finholt 2009).

e-I development and evolution thus involves simultaneous work on many fronts. For example, e-I design needs to serve as a bridge forwards towards future anticipated users/uses. At the same time, e-I implementation involves building workable bridges between necessarily generic features of the e-infrastructure and the particular locales of use. This calls into question the traditional privileging of systems design in much of the early Science and Technology Studies and social oriented computing literature, and its treatment as a discrete, prior episode in isolation from implementation. e-I development is about evolving user practices as well as system design efforts – a process which Pipek and Wulf (2009) describe as *infrastructuring*. Hepsø and colleagues (2009) make a similar point in describing this interplay between top down and bottom up efforts as *ecologies*. Actors involved must make choices about the architecture of an e-I: choices about boundaries and alliances; about which black boxes to open and which to leave shut. These *configurational politics* (Sahay et al. 2009) shape the techno-political landscape (or 'translation terrain') for the subsequent (ongoing, more or less overt) conflicts and negotiation to which the evolution of e-Is is subject. Ribes and Finholt (2009) note that those trying to initiate, promote and grow e-Is need to integrate short-term tactics within longer-term strategies to institutionalise roles and organisations. These are also issues about bridging multiple temporal scales - which Ribes and Finholt (2009) describe, after Braudel (1949), as 'The Long Now' (*longue durée*). Efforts to grow infrastructures are thus deeply paradoxical. For example, e-I design strives to cater for all purposes including those not yet envisaged – but, given the unpredictability of these activities and goals, these anticipatory efforts necessarily fail. Today's imagined future-proof systems rapidly become tomorrow's legacy systems.

7.1 Tensions and contradictions: Theorising the dynamics of e-Infrastructure evolution

Given this state of affairs, can we find a way to theorise the dynamics of e-I evolution? We have argued earlier about the need for frameworks that can give due attention to both stability and dynamism and that will capture the ways in which particular contingencies and reconfigurations will open up different pathways and generate different outcomes (Jørgensen & Sørensen 1999, Williams et al. 2004). Can we, in particular, find a mode of analysis that will avoid the already noted pitfalls of dichotomised modes of analysis (e.g. between Can-Do and No-Can-Do interpretations)? For example, are there concepts that can help us capture both the short-term resistance to aligning around particular classifications and standards and the longer-term alignment that may arise as these once contested components become taken-for-granted and infrastructural?

Ciborra et al. (2000) have addressed the contradictory requirements surrounding the development of increasingly complex and wide-reaching inter-organisational systems – and the pressures thereby arising both to increase the number and range of users and to increase the scope of activities that are supported. They describe a shift from "Control to Drift", as attempts to reconcile the increasingly diverse and complex array of stakeholder requirements and uses inevitably derail developer intentions. This pessimistic formulation runs the risk of offering a fatalistic account of the necessity of failure. In contrast, Gerst (2006), in her study of the emergence and evolution of a large e-I (a portal for automotive industry component procurement) shows how the senior managers involved deployed considerable reserves of past experience in anticipating and alleviating the social and technical problems that might emerge. Though there is no 'correct solution' that would resolve the competing exigencies the decision-makers are grappling with (for

example increasing integration within the organisation is in competition with another exigency - of aligning the systems of multiple vehicle builders), the outcome is what she describes as 'managed drift'. A growing body of analysis has begun to address such tensions ad contradictions surrounding e-I and other complex systems development (Hanseth et al. 2006, Gerst 2006, Ure et al. 2009).

The analysis of tensions and contradictions provides an alternative to the dichotomisation in modes of analysis we have previously described, between for example modernist and critical accounts that, respectively, promote and dismiss the claims of technology induced restructuring of organisational practice. Instead this work highlights incremental and partial changes, which may contribute to thoroughgoing transformations over extended periods of time. Those seeking to steer such developments with only incomplete understanding (and given the inevitability of changes in system goals, tools and context that surround their long-term evolution, such complete knowledge is only reliably available with hindsight). For actors needing to make decisions under such circumstances these concepts draw attention to the difficult trade-offs that must be made between competing exigencies, as well as the reflexive efforts of players involved to anticipate and accommodate these and achieve 'do-able' solutions.

8. Applying these concepts to analysing Health Infrastructures

How can we apply these concepts to understanding the evolution of e-Is in Health?

Findings from other application domains and sectors are relevant to Health e-Is. Indeed ERP systems have been successfully ported across from manufacturing and private service to public services including Higher Education and Local Authorities (see for example Pollock & Cornford 2004, Pollock et al. 2007), and have been proposed as a solution for health service organisations as a means of overcoming long-term weaknesses in their utilisation of IT to achieve better integration of information within the organisation. More generally we see a shift towards supply of health information systems as Commercial-Off-The-Shelf solutions (Martin et al, 2007a, Johannesen and Ellingsen 2009, Johnson 2009, Johnson forthcoming) in pursuit of anticipated cost savings and dependability advantages.

At the same time, the integration challenge in health services outstrips pretty-well all other commercial and public sector organisations in terms of both scale and complexity. Health services in developed economies represent some of the largest and most complex organisational structures of all time. For example, the UK National Health Service (NHS) is one of the largest employers in the world with around one million staff, spread across some two thousand hospitals as well as the widely dispersed primary care system with some 40,000 general practitioners.[viii] Major IT investments have been proposed for more than a decade as a way of tackling these organisational challenges, responding to political pressures to improve efficiency and quality of service.

Currently emerging Health e-Infrastructures (HeIs) thus represent a rather different sociotechnical terrain to the ERP systems previously described, which are integrated solutions promising sharing of information between the range of functions across a single organisation. Today's Health e-Infrastructures are geared towards inter-organisational integration at the interface between the multiple differing organisations involved in health service delivery and, for governance and research purposes, across the entire health service (comprising a huge array of hospitals, clinics and general practices) as well as intra-organisational information integration (Norris 2002). They seek to offer improvements in health service delivery through more effective sharing of information between specialised functions in secondary care and especially between secondary care

and the highly dispersed primary care system.[ix] Moreover in public health systems, demands for better management of resources create powerful additional political incentives to link systems together - for instance by linking in local systems to centralised databases to allow health professionals across the service to access to Electronic Patient Records for their patients.[x]

The creation and evolution of Health e-Is, perhaps above all, exemplify first, the need for an analytical shift from a 'discrete systems' to an 'infrastructural' perspective and second, the need to explore long-term biographies rather than isolated moments and sites of change. One feature is the long duration of information systems in health care and especially of the information that they contain (patient records need to last a lifetime for healthcare purposes; perhaps even longer for research purposes). Though acknowledging that HeIs present both a larger scale and a higher level of complexity than most enterprise level solutions in other sectors, both face similar issues – for example around how to cater for the diversity of user requirements and activities – and the consequent need for suppliers to pursue generification strategies in designing packaged solutions (Johannessen and Ellingsen 2009, Hyysalo 2010). These challenges have underpinned some of the, widely publicised, implementation difficulties often encountered with HeIs.

Health care work does of course exhibit a number of features that distinguish it from manufacturing activities and even from other public services like local government and higher education settings we addressed in our ERP studies. We note, in particular, the centrality of expert judgement in clinical diagnosis and treatment, the ongoing elaboration of expert knowledge and practices, reflected in strong professional autonomy and a high degree of professional and departmental specialisation.[xi] These circumstances may resist the kinds of alignment and formalisation that underpin the adoption of the kinds of standardised packaged solution that have been seen with ERP and associated ideas of a single central information kernel. However it would be unhelpful and misleading to portray health services as wholly exceptional.[xii] International classification systems have been successfully introduced into health care (Bowker and Star 1999). In addition we see the widespread resort to packaged solutions in health service information systems procurement. And, though the barriers to alignment in knowledge codification and practice are great, we must remember that information systems integration needs to be analysed as a cumulative process: local efforts in realising health information systems provide the foundations for subsequent extensions in the spread and scope of health e-Is (though for the reasons outlined above they may be unfolding at a slower rate than in other sectors).[xiii] In short, the biographies of the evolution of e-Is in health services will have distinctive differences from other sectors. They will also encounter similar, indeed homologous, challenges. The BoA perspective and its application to analysing e-Is specifically seeks to improve understanding, providing tools for comparative analysis of the evolution of e-Is in their differing settings.

8.1 UK Health Infrastructures: Connecting for Health (NPfIT)

The UK presents a particular challenge for researchers seeking to characterise the evolution of health e-Is given the huge investments currently being made by the UK NHS in the National Programme for Information Technology (NPfIT; subsequently renamed Connecting for Health).[xiv] This major programme, launched in 2002 with a projected £7bn budget, was the largest non-military procurement in the world. By 2008 it was already 4 years late and costs had risen to £12.7 billions (National Audit Office 2008). Substantial savings, estimated at more than £860 million, have been secured through centralised procurement of software through a limited set of Commercial-Off-The-Shelf solutions (Johnson submitted paper).

Some dissatisfaction has been expressed from the outset within the health service with NPfIT and with the component applications and services of the system installed to date. These have flagged usability and reliability problems, and frustrations that the new systems installed did not always match the level of functionality of the old systems they displaced. This has been associated with an ongoing and occasionally intense debate, which has involved a number of leading figures in the study of computing, about the philosophy and architecture of this 'System of systems'. An early longitudinal study has flagged the competing institutional exigencies surrounding this development (for example, between patient choice, professional autonomy, efficiency) which may impede it fulfilling its goals (Currie and Guah 2007). Packaged supply of solutions has thrown up a number of issues. In particular, the initial NPfIT specifications did not anticipate the extent of demands for additional functionality by adopting NHS organisations, which continued to the later stages of the programme. The consequent escalation of development costs for the suppliers threatened their profitability. This led to restructuring of the supply system (withdrawal of suppliers and mergers of weaker players) which had been established to avoid monopoly in provision, with most Strategic Health Authorities choosing between two major configurations (Cerner/BT's Millennium system, and Lorenzo from CSC and IBA Health) ((Johnson submitted paper).

A number of commentators have expressed concern about the centralised architecture of the NPfIT system, and in particular its central Data Spine, a central national database where summary patient records are stored. This centralisation has been seen as amplifying the dependability and privacy risks of failures (Randel 2007, Peltu et al. 2008). Different architectures for integration, it was argued, could dissipate these risks. Thus Randel argued (2007:222) for "Evolutionary acquisition: Specifying, implementing, deploying and evaluating a sequence of ever more complete IT systems". This kind of 'socio-technical' approach has been espoused as also offering greater scope for adapting systems to the needs of local users (Eason 2007). These writings thus foreground many of the same issues that we have seen surround e-I development. These discussions also draw attention to some of the distinctive features of the NPfIT, which distinguish it from previous technical change programmes in the UK and from developments elsewhere. Indeed, comparison between different national patterns of health technology acquisition (see for example Ellingsen and Monteiro 2006, Currie and Guah 2007, Johnson 2009, Hyysalo 2010) highlight many differences in the way that the vision of e-health has been pursued and the overarching influence of the particular diverse governance, financial and institutional settings of national health care systems which stamp their mark on e-I development).

To date our own research has managed to engage with only small strips of these complex developments (see for example Bunduchi et al. 2005, 2006; Anderson et al. 2006, Hardstone et al. 2006). The enormous scale of these developments, the diversity of specific computer systems being linked together, their coupling with changes in the organisation of health care delivery and its management all present profound challenges to researchers pursuing an adequate account of these unfolding developments. The various specific studies we have been involved in provide interesting pointers to the current large-scale, rapid evolution of the UK health infrastructure, but can only be seen as initial survey points on a much larger map. Some longitudinal analyses of NPfIT have been undertaken (for example, Currie and Guah 2007). However in the UK setting, any particular local study seems dwarfed by the overarching scale and scope of developments. Capturing these adequately presents very different analytical challenges than many preceding organisational technologies. This is not an argument against the application of a BoA perspective, but instead underpins the necessity of a broader

analytical perspective, and tools to allow individual studies to be integrated within a bigger picture.

9. Conclusions

The starting point for this paper was our critique of some of the prevalent models adopted for social scientific research into technology design and implementation. We have noted here our frustration with the research designs and epistemologies not only of impact studies driven by supply side perspectives, but with more critical studies, often based on ethnographic methods, and informed by more sophisticated frameworks such as Actor Network Theory, social interactionism and ethnomethodology. We criticised the naïve methodologies often adopted – for example the popularity of single site ethnographies of technology adoption – as well as the segmentation of research between technology design and implementation that results from both disciplinary divisions and the practicalities of short-term research. These had produced an inadequate and polarised account of technological and organisational change. There has been a marked failure to reflect upon the ways in which particular forms of research design may be associated with particular findings.

To overcome these shortcomings, we proposed the *Biography of Artefacts* (BoA) framework and have further refined it as an outcome of a long-term programme of collaborative enquiry into the emergence of Enterprise Resource Planning (ERP) and its predecessors. This perspective is underpinned, we argued, by the need to address technologies at different moments in the systems development life-cycle (design, implementation, use and further enhancement) and their broader product cycle (encompassing the shift from emerging to mature products and their subsequent extension and evolution). This is not a criticism of ethnographic methods which have shown themselves to be particularly helpful in understanding richness of local contexts and the detailed social interactions involved in technological innovation. However rather than unreflexively selecting particular sites of study (typically sites of technology adoption) we proposed instead *strategic ethnography*, guided by a provisional understanding of the moments, locales and nexuses in which artefacts and attendant practices and knowledges were being created, exchanged, traded and validated. Our intellectual journey, occasioned by a study of ERP emergence and evolution, seemed particularly relevant to our growing interest in e-Infrastructures.

The first generations of information systems, localised around particular tasks and professional/organisational structures, have in turn provided the foundations for the progressive extension of information sharing across departmental and functional boundaries, resulting in the emergence of the large scale information systems with multiple users and uses, that we have described as e-infrastructures. These developments call into question both the technology design/management frameworks deployed by practitioners and the analytical tools of social scientists studying them. For example, previously separate research traditions have addressed, respectively, the intra-organisational extension of systems and the emergence of inter-organisational networks/systems. The analysis of e-Is that we have begun to develop here has drawn insights from both traditions.

The huge sunk investments in data and systems in e-Is mean they are long-lived and have to cater for extensions to the activities supported and unanticipated changes in technical environments and social purposes to which they are directed. An exploration of e-Is thus requires an evolutionary analytical framework, that can address multiple temporal scales. The BoA perspective seeks to provide analytical tools for such long-term exploration and is itself informed by an analysis of the complex and protracted interplay between actors

and intermediaries in technology supply, implementation and use that we have analysed under the rubric of *social learning* in technological innovation (Williams et al. 2005).

These considerations suggest the need to reflect upon the mission of CSCW. The goal of CSCW and much socially-oriented computer science has been to attend to the 'highly flexible, nuanced, and contextualized' character of collaborative human activities and develop systems develop systems that will support these effectively (Ackerman 2000: 197). Without rejecting this mission, our argument supports a shift in perspective away from its traditional focus on the design from scratch of discrete systems (informed by workplace studies). This shift has already been flagged by a number of CSCW proponents (notably, Büscher at al. 2001,Martin et al. 2006, Johannessen and Ellingsen 2009). Specifically, this suggests:

i) an altered view of the system design and development process not as *ab initio* design, but as a process of configuration (Fleck 1988, Stewart and Williams 2005) - also described by CSCW writers (e.g. (Büscher at al. 2001) as 'bricolage': the skilful selection, combination and reworking of an array of already existing components (hardware, software, classification systems, organisational processes) and their integration with new components; and,

ii) an altered view of how and where to engage with organisational users. Thus workplace studies might usefully go beyond studying the *status quo ante* and instead address the evolution of technology and work over time. In particular, attention may perhaps most productively be focused on how organisation members engage with newly implemented technologies, since, as Fleck (1988) observes, the 'implementation arena' constitutes a key site for innovation in which organisational users engage with and explore the affordances of new technology systems and where new practices are elaborated – a space in which social learning is particularly intense and where new innovation opportunities are thrown up that may enhance future application development. Moreover these locales bring analysts (and suppliers for that matter) into in contact with actual users in real settings of everyday use, yielding more detailed and robust understandings of emerging user requirements. This can arguably generate information with more immediate implications for system enhancement and evolution.

iii) a broader view of development activities and thus of spaces for analysis and for intervention. Recognising the diverse kinds of activities which are salient in system development and evolution, takes us outwith the traditional sequential presumptions of when and where design takes place, to include, for example, system configuration, integration and testing activities (Martin et al. 2006). For example, issues about hitherto unrevealed diversity in the practices and requirements of user organisations frequently surfaced late in the procurement process, in the course of package implementation and initial use. As a result, negotiations about how far these can be met often took the form of conflicts over the contract with the supplier (Anderson et al, 2006, Martin et al. 2007a).[xv] Attention has been drawn to the importance of *integration work* in relation both to the adoption of COTS solutions (Martin et al 2007) and in the development of e-Is (Monterio and Ellingsen 2003, Johannessen and Ellingsen 2009) – involving not just technical integration of components but efforts to integrate practices across organisational divides and to link them with applications. As Martin et al. (2007: 56) succinctly state: "The 'design problem' becomes concerned not so much with the simple creation of new technical artefacts or the 'computerization' and replacement of work practices as with the effective integration of computer systems with existing and developing localized work practices."

A further corollary is that socially-oriented computer-science, including CSCW, may need to rethink its received attitude towards the spread of ERP and other packaged solutions

which have come to be the major way in which organisation-wide solutions are acquired. On the face of it, ERP systems, with their libraries of standardised business processes and centralised databases, would seem to constitute the antithesis of the CSCW project (c.f. Taylor and Virgili 2008). In contrast to the emphasis of ethnomethodological and interactionist accounts on the 'unique adequacy' of organisational processes - and thus also the need for specificity of designed systems and of methods of creating them (Voss 2006) - our studies have suggested that packaged solutions have prevailed because they offer workable 'bridges' between generic organisational/informational templates and the particularities of diverse organisation practices. The prevalence of packaged ERP solutions cannot be simply attributed (as some have suggested) to the success of powerful vendors in marketing their products to naïve organisations (though issues of supplier provenance [past reputation; future prospects] do figure in procurement decisions [Pollock and Williams 2007]). Their adoption has, moreover, not been without cost and effort and includes a number of widely publicised instances of failure. Nevertheless, large numbers of organisations have adopted them. We suggest that standardised enterprise solutions have been adopted because they provide an information and IT architecture around which organisational information systems can be constructed and do this (stakeholders presumably believe) more cheaply and more robustly than by building such systems from scratch. This is not to suggest the 'victory' of standardisation over local diversity – standardisation of information systems and practices across different groups and organisations is always incomplete and has paradoxical and unintended outcomes (Anderson et al. 2006, Ellingsen and Monteiro 2003).[xvi] It is important, however, to acknowledge, as well as barriers to standardisation, the gradual sedimentation of certain standardised procedures, codifications, technologies – which provide the foundation upon which further differentiation and elaboration (and, in due course, further integration and standardisation) efforts take place.

As a result, socially oriented computing and CSCW specialists need to pay attention to the longer-term evolution of technologies and practices. Here the BoA perspective offers not only methodological guidance but also analytical cues regarding the variable dynamics of innovation in differing contexts (for example at different stages of maturation of a technological field). This bears also upon the opportunities for intervention (Stewart and Williams 2005). These in turn are strongly influenced by the location of a particular technology offering or technical field in the 'historical arc'[xvii] of its development. For example, in the early stages of the evolution of an information infrastructure, development processes may be relatively open, and particular organisational groups may seek to articulate their purposes through new system development. At later stages, however, the 'translation terrain' (Williams et al 2005) on which further development takes place is more complex - already densely populated by past investments and players. These on the one hand provide resources around which new systems will be installed. However, on the other hand, as a result of these commitments and alignments, many technical and social options may be effectively closed off (Sahay et al. 2009). As a result, in these later stages of information system/e-I evolution, further development opportunities may be primarily for local reconfigurations within a broader already formed information infrastructure. There will of course be periods in which a more radical restructuring of information systems and their underlying architectures prevail. But even here, we suggest, we are likely to find increasing resort to large-scale packaged solutions, given the enormous cost and dependability advantages of recycling code.

These issues are likely to become increasingly salient in relation to health information systems and e-Is. Thus Johannessen and Ellingsen (2009) have noted the different challenges in the supply of health e-Is in a case in which an information system, designed

for one customer, is transferred to other contexts and subsequently to a larger market. The generification strategies adopted by the integration supplier in this study bear striking resemblances to the generification strategies articulated over time by our ERP suppliers.

This is not to argue against the CSCW project – but to suggest that there needs to be some reinterpretation of the project, as we move to a situation in which work activities are conducted through extended heterogeneous e-Is rather than discrete systems. In this context, developments are of necessity inevitably partial interventions within the broader, longer-term evolution of e-Is. We are not the first to make this observation, of course. We note important contributions from others (including many members of the CSCW community), based on work which is frequently directed at the health domain. These draw our attention, for example, to the emergence of efforts directed towards *integration* between existing services, rather than discrete systems design (Ellingsen and Monteiro 2003, Martin et al. 2006, Martin et a. 2007, Johannessen and Ellingsen 2009). Moreover in these contexts, some of the issues around e-I emergence are salient such as balancing multiple local and central requirements, and the consequently complex and paradoxical (sometimes unintended/undesired) outcomes of such developments (Ellingsen and Monteiro 2003, Winthereik and Vikkelsø 2005, Anderson et al. 2006, Martin et al. 2007a, Johannessen and Ellingsen 2009). In these evolving contexts, the long-established commitments and concerns of CSCW practitioners may need to be expressed in different ways. As Turner et al. (2006: 96) argue (in relation to e-Is in e-science rather than e-health) "the objective of CSCW should be less that of providing designers with blueprints for engineering locally coherent sociotechnical systems, but more that of providing system users with the power of constantly reconfiguring them in order to build for themselves roomier, more comfortable milieux in which to carry out their collective activity."

e-Is are becoming more widespread, pervasive and salient in health and other sectors. There is, accordingly, a growing number of studies of particular instances of emerging e-Is – not least in Health services. We have proposed a systematic programme of enquiry into e-Is, especially HeIs (and their biographies). Comparative studies between different kinds of e-I may offer important insights (Edwards et al. 2009) – and there has been a recent conceptual flowering of work in this field. Some of this work, as revealed by the brief review above, has thrown up valuable new conceptual tools – which can contribute to the development of analysis of the biography of e-Is.[xviii] However, we are still in the early stages in articulating this framework. We hope this brief paper has been able to provide pointers and tools for the intellectual journey to come.

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[i] Though we use the term e-infrastructure we note that these various terms (cyberinfrastructure, information infrastructure etc) are used in inconsistent and overlapping ways.

[ii] We find it interesting that there are very few CSCW studies of ERP implementation. (Indeed, the area of packaged software appears rather strangely to have been mostly ignored by this group of scholars). The few studies we did find, however, exemplified similar aspects of the more general information systems literature in highlighting the gap between expectations and outcomes. Taylor and Virgili (2008: 68), for instance, write: '...it then became possible to conceptualise the gap between current modes of working, and those that SAP envisioned. As this process transpired, however, the complexity of the SAP technology was also beginning to reveal itself. How to reconcile accepted practice and new system now became less a simple matter of identifying discrepancies and correcting them than it did of finding a way to deal with the intractable realities of practice either by modifying the technology, or abandoning the practice—or both. This was not exactly the way the development process had been envisioned. It was more complex—considerably more'.

[iii] Indeed classical ethnography, which involves immersive acquaintance with what is involved with being 'a member of the tribe', might in many ways escape our critique of short-term, local case-studies.

[iv] Our critique of the naïve empiricism of localist studies (especially those inspired by ethnomethodology) also applies to the simplistic methodological nostrums of Actor-Network Theory (ANT) as exemplified by Latour's (1987) much cited exhortation to 'follow the actor'. This begs the obvious question – "which actors should we follow?" (see Sørensen and Levold 1992). What is at stake here is an orientation to theory. ANT Theorists have argued against the resort to the existing body of social science findings on the grounds that these may offer misleading generalisations and presume that the world of tomorrow will simply repeat patterns entrenched in current structures. Similarly, ANT writers suggest, social science methodologies embed potentially misleading presumptions about what are the key factors at play – and in this way may unintentionally constitute reality, for example by naturalising the power imputed to existing institutions (Callon and Latour 1981; Law 2004). However their claims to be able to apply 'naturalistic' observation methods, unencumbered by theoretical commitments, fall foul of well-established critiques of *empiricism,* and not least of failing to address taken-for-granted social relations (and they have been criticised for overlooking entrenched asymmetries for example of class and gender). We argue instead that the existing research base should be treated as provisionally or partially-valid background knowledge – that we can use to *inform* research design choices and interpretation rather than to *prejudge* outcomes (Pollock and Williams 2009).

[v] See previous footnote

[vi] There will be sharp differences for example between the exigencies surrounding the development of different kinds of software development – for example between complex organisational technologies discussed here and discrete or component technologies such as personal productivity tools) (Brady et al. 1992).

[vii] Arising from our work on the development of standards for inter-organisational network systems (*The Networked Enterprise: The Shaping of Institutions and Standards in E-Business.* UK Economic Social Research Council (ESRC) E-Society Programme), we (Ian Graham, Robin Williams, Neil Pollock) organised an international research workshop on "Information Infrastructures and Architectures" (e-Science Institute, Edinburgh 27-28 September 2006 http://www.nesc.ac.uk/esi/events/700/). By coincidence Edwards and colleagues in the USA simultaneously organised a National Science Foundation funded Workshop on "History and Theory of Infrastructure: Lessons for New Scientific Cyberinfrastructures" in Michigan (Edwards et al., 2007).

[viii] Data from NHS Information Centre http://www.ic.nhs.uk/statistics-and-data-collections/workforce sampled 10 March 2010.
[ix] And many current visions of health service reform envisage the extension and integration of services, and the IT systems that support them, between health and social care.
[x] The centralised architecture proposed in England for an electronic Summary Care Record that will be available to NHS staff involved in a patient's care, anywhere in the country, has proved rather controversial, in a context in which some have expressed deep concern about the confidentiality of Electronic Patient Records. The potential sensitivity of information stored on Health e-Is, as well as the clinical importance of data integrity, underpin the strict regulation of access and exchange of health information, and has a profound influence on system design and architecture and the procurement and implementation process. The competing exigencies – for example the stringent data protection requirements for personal health data coupled with the frequent need to share such data for risk abatement and effective care (Norris 2002) - create additional contradictions to the development of health e-Is.
[xi] Personal correspondence with Sampsa Hyysalo 18th March 2010.
[xii] Indeed there are evident similarities between the visions and models of change between healthcare and other industrial sectors, including the notions of information integration as well as a process orientation to technology enabled restructuring (Norris 2002; Bragato and Jacobs 2003).
[xiii] A wide range of other factors have been advanced to help explain the particular difficulties that seem to be associated with information technology adoption in health services. As well as their complexity and large scale, these include organisational fragmentation and the difficulties integrating political reform with the often rather longer timeframes for large-scale procurement, implementation and evolution of health e-Is (Johnson 2009). As a result, despite an extremely long history of IT adoption in health services, dating back to the 1960s and before, we do not always find the *cumulative* development of IT capabilities and infrastructures. At the same time, our colleague Mark Hartswood has drawn our attention to an implication of our analysis (personal communication, 30th March 2010) that the emergence of Health e-Is is inevitably going to be a 'long road': a mixed bag of failure and partial success in the development and maturation of generic technologies and systems that support complex organisational work over a number of decades.
[xiv] See http://www.connectingforhealth.nhs.uk/ The description that follows addresses the unfolding of NPfIT in its major area of England. Other parts of the UK have followed somewhat differing approaches.
[xv] As we have noted elsewhere (Pollock and Williams 2009: 66), market provision of complex organisational solutions frequently encounter 'incomplete contracting' issues. Though effective monitoring of the contract calls for strict prior specification of customer requirements which can be embedded in the contract and their fulfilment policed, in practice the user organisation only has an imperfect initial understanding of its own requirements, which invariably evolve as the system becomes implemented, partly in reaction to the capabilities of the package.
[xvi] For example, as Anderson et al. (2006) observe, when classification systems become embedded in organisational software solutions, deficiencies in agreeing classification systems are transposed into a categorisation problem – of getting idiosyncratic events to conform to standard categories.
[xvii]Personal correspondence with Mark Hartswood 30 March 2010.

[xviii] Indeed these tools developed for analysing the evolution of e-Is can also contribute to analyses of the biographies of other large-scale, complex and evolving technologies.