Scandinavian Journal of Information Systems

Volume 28 | Issue 2 Article 2

12-31-2016

Doing Infrastructural Work: The Role of Boundary Objects in Health Information Infrastructure Projects

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Cover Page Footnote
The authors acknowledge the support of the Australian Research Council (DPDP110100084) and the interviewees in Australia and the UK who contributed to the research on which this article is based. We would like to thank SJIS's anonymous reviewers and editors for their constructive and helpful comments on the paper.

Doing Infrastructural Work

The role of boundary objects in health information infrastructure projects

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Abstract. By their nature information infrastructures require the co-operation of a broad range of diverse stakeholders and interests in order emerge and evolve over-time. Boundary objects provide a means through which those from different social worlds can collaborate without having to reach a consensus in order to do so. In this article we explore the role of such objects, whose infrastructural properties have often been overlooked. We respond to calls to examine the different types of objects used to elicit feedback from potential users and other stakeholders in complex information system projects. Our focus is specifically on health information systems and in particular those involving the implementation

Accepting editor: Bendik Bygstad

of electronic record systems at a national or regional scale. Such projects are notoriously complex and are frequently marked by a diversity of intentions and lack of agreement. When attempted at a national scale at least, they typically fail to meet intended objectives and projects are often abandoned altogether. We suggest that understanding how different types of boundary object—repositories or ideal types—inhibit infrastructural development can assist in understanding these difficulties and point to ways of better supporting the generativity required for the infrastructuralisaton of complex information systems.

Key words: information infrustructures, boundary objects, health information systems, electronic health records, sociomateriality.

1 Introduction

The emerging field of infrastructure studies (Sandvig 2008) has challenged the conventional view of information systems as digital artefacts which have fixed embedded technical capabilities and characteristics (Martin 2014; Monteiro et al. 2013). Instead attention has been focused on the generativity of digital systems, and in particular the way they "allow individuals, groups, and organisations to co-create services, applications, and content" (Tilson et al. 2010, p. 750). In their more globalised and networked forms it is suggested that information systems are now better understood as information infrastructures constituted by increasingly numerous and heterogeneous technical components that interact with social relations in "dynamic and unexpected ways" (Hanseth and Lyytinen 2010, p. 1). A defining feature of information infrastructures is that they necessarily emerge and evolve over lengthy timescales where generativity is instantiated in ongoing design-in-use shaped by a plurality of intentions across a wide variety of organisational and other contexts. This contrasts with conventional views of the development of information systems where discrete artefacts are designed a priori with relatively clear intentions in discrete episodes and organisational locales (Monteiro et al. 2013).

This article seeks to contribute to our understanding of the new challenges involved in coordinating design-in-use during the development of health information infrastructures. We do this by exploring the possibility for boundary objects to do some of the infrastructural work necessary to enable infrastructures to evolve. Boundary objects are significant in so far as complex information systems require, "the active participation of a wide range of internal and external stakeholders" often working in "cross-disciplinary and temporary project-based settings" where a key challenge involves, "representing, negotiating and integrating the diverse knowledge, viewpoints and interests" of different stakeholders and other interested parties (Doolin and McLeod 2012, p. 570). The challenge of creating a shared understanding in such circumstances often means that a, "range of project-related artefacts" are called into play to "mediate this process" (Doolin and McLeod 2012, p. 570). We suggest that such mediation is highly significant for the infrastructural work that is required to enable the development of information infrastructures.

In the classic definition, boundary spanning objects may enable divergent groups to reach sufficient agreement to design and implement a resource of some kind—including of course computer artefacts and information system; e.g.; (Barrett and Oborn 2010; Doolin and McLeod

2012; Star and Griesemer 1989; Winter and Butler 2011; Zolper et al. 2013). However, one often overlooked feature of boundary objects is that they also do infrastructural work (Star and Ruhleder 1996; Star 2010). Our aim in this article is to explore this aspect of the potential role of boundary objects in the development of electronic health record (EHR) systems, an example of complex information systems projects which face particular co-ordination and collaborative challenges when attempted at a scale beyond the individual healthcare enterprise. In so doing we seek to contribute to the call for systematic explorations of infrastructural development "across contrasting sociotechnical settings with their different coordination challenges, scale, number and range of users, institutional settings, and resource availability" (Monteiro et al. 2014, p. vii).

Our discussion proceeds as follows. First, we review the idea that boundary objects can do infrastructural work that enables on-going user engagement and collaboration to support design-in-use. We argue here that boundary objects may do work which can support what have been referred to as the generative mechanisms essential for infrastructures to evolve. We then describe our research design, methods and case studies which focus on two large national and two small regional EHR development projects in Australia and England respectively. In each case we provide narrative accounts that illustrate the challenges and opportunities for consulting with and engaging potential users in system development in national compared to smaller regional projects. In the concluding discussion we develop our contribution to infrastructure studies by suggesting how certain types of boundary objects can do work that can either enables or hinders the development of information infrastructures.

2 Boundary objects and information infrastructures

The concept of boundary object was introduced nearly three decades ago by Star and Griesemer (1989) to theorise how actors from markedly different backgrounds and social worlds were able to collaborate during collective ventures without necessarily having to achieve a consensus in order to do so. In their classic definition, boundary objects:

> …inhabit several intersecting social worlds and satisfy the informational requirements of each of them. [They] are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. (Star and Griesemer 1989, p. 39)

In Star and Griesemer's research, boundary objects typically took the form of material artefacts such as written plans, lists, databases, standardised forms and classification systems, which could be used to coordinate work across occupational, social and geographical boundaries. The concept has subsequently been taken up by researchers in several disciplines. In the case of information systems development researchers have focused on a variety of project-related artefacts that perform the functions of boundary objects including representations of design solutions, contracts, requirements specifications, project management tools, and system prototypes (Barrett and Oborn 2010; Doolin and McLeod 2012; Gasson 2006; Levina & Vaast 2005).

A key finding has been that, whatever the object concerned, to be effective in spanning boundaries putative boundary objects need to support shared social action or joint fields of

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practice (Levina and Vaast 2005) and to be sufficiently flexible to be able to accommodate different interpretations and understandings (Star 2010). Further, if they are to successfully translate into boundary objects-in use (Boujut and Blanco 2003; Lee 2007; Papadimitriou and Pellegrin 2007), they also need to facilitate relational boundary spanning activities which both create and steer joint fields of practice towards mutually beneficial outcomes (Levina and Vaast 2005). Finally, boundary objects are necessarily embedded in power relationships and can be used by power-holders in positive ways as anchors or bridges that facilitate consultation, engagement and collaboration in a manner that addresses asymmetries of power based on the distribution of knowledge and expertise. Conversely they can also be deployed either intentionally or in error in a more negative way as rigid entities which act as barricades or mazes that close off some design options and allow only the pursuit of others consistent with the sectional interests of particular stakeholders (Oswick and Robertson 2009; Huvila 2011).

These insights notwithstanding, in one of her last commentaries on the concept, Star observed that most researchers had in the main overlooked the capacity of boundary objects to do infrastructural work (Star 2010). By this she meant that, boundary objects can allow stakeholders to tack back-and-forth between their own social worlds—where the object is made more specific and tailored to local use—to more global situations where cooperation is taking place without consensus and which requires objects to be ill structured to be effective (Star 2010, p. 604-5). As such boundary objects can be used and re-used at different times and in different places and contexts; enable links to and integration with existing work routines and practices in a way that allows an object to become an every-day part of these activities; connect to and tolerate the constraints of the existing infrastructure of the installed base; and support the further evolution of socio-technical arrangements from the bottom-up (Star and Ruhleder 1996:112). In this way, boundary objects can be thought of as doing the infrastructural work required to resolve or at least manage the inherent tension in infrastructural development, "between local, customised, intimate and flexible use on the one hand, and the need for standards and continuity on the other" (Star and Ruhleder 1996, p. 112).

Precisely the same tension has been a preoccupation of information infrastructure researchers who have characterised their development as, "a complex process where technological components, stakeholder interests, work practices and conventions" all "need to be globally aligned and locally grounded" (Grisot and Vassilakopoulou 2013, p. e172). A recent strand in information infrastructure research has focused upon the generative mechanisms necessary to allow bottom up enactments that are responsive to local complexities and contingencies whilst also enabling coordination of development across systems and domains. See; e.g.; (Grisot and Vassilakpoulou 2013; Henfridsson and Bygstad 2013). Information infrastructure researchers have noted that enabling infrastructural development through design-in-use requires solutions to be found to the problems of bootstrapping, that is how to develop systems in a way that encourages initial take-up by users, and adaptability, that is, enabling future system development in way that is facilitated and not constrained by prior design decisions (Grisot et al. 2014; Hanseth and Lyytinen 2010; Aanestad and Jensen 2011).

It has been suggested that bootstrapping might be addressed by design principles that seek technological solutions that are directly useful to a specific user community whilst at the same time acting as an attractor for future technological development and growth in user numbers. Similarly, adaptability might be addressed through design principles which stress simplicity and

modularity to support growth and integration with the existing installed base of information systems in a self-organising way (Hanseth and Lyytinen 2010, p. 5-7). Henfridsson and Bygstad (2013) go further and argue that to enable such developments what they term 'generative mechanisms' are also required. These are: *innovation mechanisms* that allow resources to be (re-) combined in novel ways to support new services; *adoption mechanisms* that encourage more users to adopt the infrastructure and in so doing increase its utility to other users in a self-reinforcing manner and scaling mechanisms which, as an infrastructure expands, attract new partners and collaborations, for example because it is easy to connect to existing or other new systems (Henfridsson and Bygstad 2013).

It is our contention that boundary objects can be regarded as means through which such generative mechanisms have be given effect in practice in specific contexts. In advancing this proposition we take note of Grisot and Vassilakopoulou's (2013) observation that, whilst the idea of an infrastructure is concerned with the "underlying structural supports which enable action, create connections, and have durability", it also incorporates relational and ecological dimensions. That is, infrastructures can mean "different things to different groups in relation to organized situated practices" and be, "part of, made of, and inseparable from actions, tools and their environment" (Grisot and Vassilakopoulou 2013, p. e172). The relational and the ecological are of course key elements of the classic understanding of boundary objects along with, as noted above, their materiality. However, those who have presented propositions concerning the role of generative mechanisms have done so from the perspective of critical realism, whose "basic assumption…is the existence of a real world independent of our knowledge of it" where entities such as "organizations, actors or systems" in given contexts can have "causal powers" in such things as the development of infrastructures (Bygstad 2010, p. 159; 161). Doolin and McLeod (2012) provide one way of reconciling these positions by arguing that boundary objects can usefully be understood as sociomaterial phenomena (see Cecez-Kecmanovic et al. 2014 for discussion of this approach).

With regard to the emergence of boundary objects in information systems development, Doolin and McLeod (2012) suggest that a, "consideration of both the sociality and materiality of boundary objects is needed to answer questions about why various project-related artefacts are more (or less) effective as boundary objects" and to understand, "how their nature and shape as objects differs with the work and informational needs of the communities involved" (Doolin and McLeod 2012, p. 571). This has a number of implications for how boundary objects and their functions can be understood. First, they cannot exist "independently of the sociomaterial practices in which they are located" and are both "performed in practice" and shape the performance of that practice. Second, and following from this, boundary objects are dynamic and open phenomena that are, "subject to the possibility of future adjustments and reconfigurations" in order to overcome new "obstacles in the integration of knowledge" or develop new directions for existing knowledge. Third, the capacity of a boundary object to become an object in use is not something inherent in the object but "arises from the sociomaterial agency that is realised in the constitutive entanglement of the two". Fourth, the performativity of a boundary object varies across time, space and context and "different performances constitute communication, translation and knowledge sharing in particular ways, with varying consequences that are social and material, intended and unintended" with the possibility for different outcomes, be they positive or negative. Finally, rather than understanding boundary objects as the same thing which

can be interpreted in flexible ways by different stakeholders, they are multiple entities that are "performed and come into being in specific sociomaterial practices" (Doolin and McLeod 2012, p. 573).

Following this understanding, we suggest that boundary objects cannot be reduced to either their relational or material elements. Instead they should be regarded as particular sociomaterial configurations or assemblages that are performed in specific temporal, spatial and organisational contexts. As such, the manner and extent to which boundary objects can function to support performativity that results in mechanisms or affordances that are generative in a causal sense is a legitimate interest and research question. In particular, by understanding boundary objects in sociomaterial terms, we can see them as one means through which generative mechanisms are given effect in practice. Accordingly we may be placed in a better position to explain not just the what, where and when of such effects but also the how and why concerning their emergence and evolution in practice and their effects on infrastructural development in particular times and places (Doolin and McLeod 2012, p. 573). In short, boundary objects provide one means through which diversity of meaning and intention can be mediated and the necessary collaboration to afford the co-production and materialisation of new and different processes and outcomes made possible in practice.

3 Research design, methods and case studies of EHR development

Health information systems, in particular those involving the design and implementation of electronic health records (EHRs), have provided a prominent focus for information infrastructure research and in many aspects provide a paradigm case of such developments. See; e.g.; (Bjørn and Kensing 2013; Eason and Waterson 2013; Ellingsen et al. 2013; Ellingsen and Bjørn 2014; Grisot et al. 2014; Halford et al. 2010; Hoerbst et al. 2011; Jenkings 2004; Jensen 2010; Jones 2004; Klöckern et al. 2015; Rodon and Chekanov 2014; Monteiro, et al. 2014; Zwaanswijk et al. 2011; Aanestad and Jensen 2011). Indeed, the development of EHR systems at a scale above the single healthcare enterprise, appears to provide a particularly tough case for infrastructure development.

For example projects, especially those conducted at a national level, typically adopt top-down specification driven strategies in which stakeholder agreement is sought on standards and their specification through committees or other consultative processes tasked with defining functional requirements (Grisot et al. 2014, p. 199). Here the key design elements of systems are deliberately, "specified in advance on the expectation that they will persist for the whole lifetime of the system" which is "assumed to be stable" once implemented (Grisot et al. 2014, p. 199). Almost invariably these types of projects have run into trouble, been scaled-back and sometimes abandoned altogether. See; e.g.; (Bowden and Coirea, 2013; Cresswell and Sheikh 2013; Deutsch et al. 2010; McLoughlin et al. 2017; Stroetmann et al. 2011). In contrast, projects in smaller national jurisdictions (typically those below 10 million population)—along with those attempted at a regional or more local level within larger nations—have reportedly been more

successful in realising benefits (Greenhalgh et al. 2009; 2013; Kierkegaard 2015; Stroetmann et al. 2011). Here, more bottom-up approaches are typical and seem to facilitate projects that have at least the potential to evolve in a more infrastructural manner. That is by: developing the minimum necessary for a system to function; evolving this functionality as the number of users grow gradually; and allowing standards to emerge rather than being agreed at the outset (Grisot and Vassilakpoulou 2013:170; Grisot et al. 2014; Henfridsson and Bygstad 2013).

As Hyssalo (2010) notes, such phenomenon are not as yet well understood and there has only been limited exploration of the different types of objects used to elicit feedback from potential users and other stakeholders in health information system projects of different scale and scope so. Indeed, more so than in most other instances of information system development, projects in healthcare require groups with very divergent interests and from vastly different social worlds to work together; e.g.; government policy-makers and bureaucrats, system vendors and developers, health sector managers, clinicians of different status and specialisations and their professional bodies, patients, consumer representatives, privacy advocates and watchdogs. Moreover, system development involves capturing and synthesising relevant knowledge from a similarly wide variety of organisational and other domains; e.g.; primary care, hospitals and other healthcare providers, patients and patient groups; and occupations; e.g.; hospital doctors, general practitioners, nurses; to produce outcomes that function in different contexts and relationships where the information involved is highly personal, sensitive, has high standards of providence, and is open to interpretation which is highly context dependent (Garrety et al. 2014). The idea of sharing health information by digital means is also controversial. For policymakers and other proponents it will result in greater "choice, empowerment, quality, safety, efficiency and personalized care" whilst for the more sceptical such developments are the product of "dangerous enthusiasms" (Gauld and Goldfinch 2006) which will at worst extend "electronic surveillance into intimate parts of citizens' lives" (Greenhalgh et al. 2010, p. 5).

We suggest that in such challenging circumstances the project related artefacts deployed to explore possibilities for shared understanding and to mediate global/local tensions in the information system development process are of considerable interest. As such they can provide a valid test of the proposition that boundary objects may do important work in enabling infrastructuralisation. In order to explore this proposition, we draw on a retrospective, comparative study of two of the most ambitious, far reaching and politically controversial attempts to build national EHR systems in developed countries—the national initiatives attempted in Australia and England over the past 15 or so years. In both cases we focus on the initial stages of national development which took place in the early 2000s as attempts were made to specify architectures, requirements, standards and functions prior to procuring and implementing nation-scale systems. Given existing research evidence noted above concerning the link between infrastructuralisation and the scale of projects we also studied two regional initiatives in each country, one in south east Australia and the other in north east England. The significance of both local projects was that they were precursors to and, in different ways, superseded by their respective national initiatives. As we will see, in contrast to their national successors they also appeared to be relatively successful in terms of their stated objectives and produced either working systems used in practice or prototypes which elicited a high degree of positive feedback, in particular from clinical users. In principle it might have been expected that lessons learnt in these smaller antecedent projects would inform subsequent larger scale developments.

Given the retrospective nature of our research the data we draw on are mainly derived from publicly available documents. The documents included policy reviews and recommendations, strategic statements, progress reports and enquiries, consultation responses and the like, from government officials and politicians, health administrators, professional bodies, privacy and consumer groups and others who constituted the key stakeholders and potential users. In addition, a vast and diverse array of public commentary was explored in specialist media, for example, in e-health and informatics journals, and in more general press articles and social media. In total we amassed over 4,600 such documents which were analysed and used to construct narrative chronologies for each case. The narratives were scrutinized and compared, with a view to understanding why some attempts to develop EHRs were more successful than others. We defined success as a capacity to deliver (more or less) the outcomes identified as desirable by those who initiated each project.

These chronological accounts were supplemented by a program of interviews. Some of the authors (who include health informaticians and a general practitioner) were also personally involved in, or close to, one or more of the four projects and this facilitated data collection and the identification of suitably informed and strategically placed candidates for interview. The interviews sought to flesh out key aspects of the project narratives and to draw on the respondent's own perceptions, informed by hindsight, of the features of each endeavour which had been more or less successful and the reasons for this. Twelve people were interviewed in Australia. Three were involved only with the regional project, three with both the regional and national efforts and six with the national project only. Ten people were interviewed about the English projects. Four were involved with the regional project, three with both the regional and national projects and three with the national project alone. Given the high public visibility and political sensitivity around the projects concerned, in particular the national cases, appropriate steps have been taken to preserve the anonymity of the interviewees. Data were collected between October 2009 and March 2015. The projects which comprised each of the four cases were deliberately chosen because of their differences in detail and scope. Each case is an example, in their different contexts, of an attempt to address the common problem of how to design and build health information systems aided in some way by the knowledge of those who will use them. The aim of our research was to refine our analytical understanding of the types of objects used to elicit feedback from potential users and other stakeholders, in such circumstances in order to make "more incisive distinctions than hitherto available" (Tsoukas 2009, p. 295; see also Greenhalgh et al. 2011).

On the basis of the retrospective data we chose a significant project-related artefact from each case that, from the available evidence, provided a primary means through which the potential future system could be conceptualized and therefore also acted, at least potentially, as foci for stakeholder feedback and engagement. The artefacts could, prima-facie, be taken to align with the classic definition of a boundary object as something intended by participants to enable their collaboration across diverse stakeholder groups and other interested parties engaged in or impacted by the project. These artefacts were:

Object 1: A Business Architecture developed during the first attempt to build a national EHR system (called Health*Connect*) in Australia between 2000 and 2005. The architecture was initially developed by system designers within the Health*Connect* project team. The purpose was to provide a high level blueprint of the system which could be refined through consultation with

key stakeholders—in particular clinicians to inform the detailed specification of the system to be implemented. Several versions of the architecture were produced as part of this consultative process and the fate of the architecture through these iterations provides a meaningful test of its effectiveness as a boundary object enabling collaboration across the diverse social worlds that constitute the notoriously complex Australian healthcare system.

Object 2: An Output Based Specification of the requirements for a national summary health record and other systems developed as part of the National Programme for Information Technology (NPfIT) in the English National Health Service (NHS) between 2002 and 2007. This object has a similar purpose as the Australian national business architecture in so far as it was designed to provide a high level documentation of the requirements of a national electronic health record. In this case this meant capturing the diverse requirements across the English NHS concerning such a system and rendering these in a form which could then provide the basis for a procurement exercise to supply the required hardware and software to implement the system on a national scale. The OBS was thus intended by its architects to have a pivotal role in providing a basis for collaboration between a complex procurement supply chain and the diverse needs and requirements of clinicians in NHS organisations across the country. Again the effectiveness of the OBS in achieving this can be proposed as a critical factor in determining the fate of the project.

Object 3: A computer interface or portal based on web-technology that enabled GPs to access hospital information on patients in their care as the core part of a local project intended to provide an electronic infrastructure for sharing clinical records across primary and acute sectors of a regional healthcare system in the south east of Australia. The resulting artefact was a portal called 'GP Gateway' and the initial development of the system formed the key deliverable of the funded phase of a project between 2000 and 2005. The portal interface was first developed in prototype form with the purpose of providing a focus for collaboration among clinicians in primary and hospital care in the electronic exchange of patient data. It subsequently evolved to include additional functionality and enroll a wider-range of clinical specialisms in its use. Key in this case was the way in which the portal supported the boundary-spanning activity of project champions, while also enabling, through a gradual bottom up process, the creation of a network that was technical as well as clinical network.

Object 4: A computer-based animator developed as part of a pilot (from 2000 to 2002) in the north east of England for a national demonstrator project which was the forerunner of the NPfIT (see above). The cross-disciplinary pilot team comprised academics—information and social scientists and practitioners—clinicians and healthcare managers. The aim of the pilot project was to demonstrate how an electronic health record might work in clinical settings in practice. To facilitate this the academic members of the team developed a computer-based animator. This was developed as a resource through which clinicians within the pilot team and more broadly in the regional health service could prototype how an electronic record might support clinicians in a particular episode of care; e.g.; an emergency admission of a patient following a heart attack.

The outcome of this process was a reference architecture which provided both technical and organisational guidelines for the development of a national electronic health record in England. The animator was therefore intended by its creators to play a pivotal role in enabling collaboration between team members and to solicit input into the design of care pathways supported by an electronic medical record that would allow information to be passed seamlessly between

Project	*Regional Australia GP Gateway 2000-2005*	*Australia National HealthConnect 2000-2002*
Boundary Object	Web-based 'portal' interface first in prototype then in 'live' form.	Business Architecture intended to provide a 'functional blueprint' for future system
Type of Object	Repository	Ideal-type
Circumstances of creation and use	Bottom-up initiative led by local GPs and funded by Federal Government. Aim to use web-based technology to link hospital information systems to GP surgeries for use in local consultations with patients.	Federal government initiative to develop a national EHR system specifying what it would do and how component elements would fit together.
Nature of consultation/engagement	Design specification informed by local GP working group who gave feedback to website developers and mobilised regional expertise to capture available information sources. Project coordinator played a key role in brokering information sharing agreements, promoting the project and take-up.	Project overseen by a board comprising government, consumer, health provider, and informatics representatives. Versions of the architecture were shown to experts on a working group before being released for public consultation involving information sessions and written responses from stakeholders.
Clinical stakeholder feedback and response	Hospital clinicians initially showed some reluctance to make data available to GPs. Some information was not accessible electronically. On the whole clinicians accepted and valued the system.	Doctors and nursing bodies complained that the architecture was too distant from their everyday health care practices, was too abstract to be comprehensible and that there was an absence of meaningful ways to influence the design which lacked key details.
Exercise of Power through boundary object	Operation of the system depended upon a partnership between hospitals, the local GP organisation and the regional health authority. Boundary Object initially very effective in facilitating innovation and adoption. However, potential for scaling undermined when system 'turned-off' due to regional restructuring.	Top down initiative driven by government policy and subject to tensions between federal and state levels. This eroded support for the project which was allowed to wither away as support was sought for a new initiative. Boundary object not effective in facilitating innovation, adoption or scaling.
Project Outcomes	System implemented and operational until shut down.	Plans and pilot trials abandoned in favour of new approach.

Table 1(a) Boundary objects and infrastructural work in the four cases

Project	*Regional England EHR Demonstrator 2001-2005*	*England National Care Record Service 2002-2010*
Boundary Object	Computer-based animator used to demonstrate how EHR service might look to users	OBS specifying health service requirements for national EHR for purposes of system procurement
Type of Object	Repository	Ideal Type
Circum-stances of creation and use	Regional project commissioned as part of a national trial to develop plans for a national health information system. The project focused on the design of an EHR in context of use.	'Top down' approach influenced by private sector procurement approaches and practice. Aim to build an entirely new health information system with a national EHR at its core.
Nature of consulta-tion/en-gagement	Socio-technical system design based on ethnographic study of clinical information sharing practices. Informed development of 'animator' which showed in mock-up form how a system might work and provided a basis for potential users and other stakeholders to co-design system.	Government doubts over the ability of the NHS to design a national information system led to technical specifications being determined centrally with minimum consultation. Subsequent attempts to engage clinicians but scope insufficient and rushed.
Clinical stakeholder feedback and response	Clinicians in project team were able to raise many questions and issues in relation to the EHR prototype in a co-design process supported by the animator and subsequently tested on a broader range of stakeholders through focus groups etc.	Significant opposition from a range of stakeholder representatives including medical profession. Resistance at hospital level. More efforts to take concerns into account in the latter stages of the programme.
Exercise of Power through boundary object	Regional demonstrator vulnerable to shift in national policy which centralized control over IS procurements. The boundary object was highly effective in facilitating innovation but was not deployed beyond the trial stage so no impact on adoption or scaling.	Top down project intended to be a central element of government modernisation of NHS. As costs and delays mounted newly elected government decided to abandon programme as a whole. Boundary object initially effective as a means of innovation in procurement but was counter-productive for adoption and scaling.
Project Outcomes	Range of project deliverables including an open and flexible reference architecture whose insights were largely ignored in subsequent developments.	Serious technical delays, cost over runs and implementation problems. Overall program eventually abandoned but more limited summary care record still being rolled-out.

Table 1(b) Boundary objects and infrastructural work in the four cases

primary and acute care providers throughout the patient journey. Our interest in this artefact as a putative boundary object was heightened by the fact that it was intended by its creators not only to elicit feedback, but also to enable clinicians to participate in the design of care pathways and clinical relationships supported by an EHR. One hallmark of this approach was the way in which the scenarios embedded in the animator were informed by detailed ethnographic observations of clinical practice in emergency departments thus providing a relatively high degree of authenticity to the situations it was able to portray.

In terms of the classic definition these four boundary objects resemble most clearly what Star and Griesemer (1989) term 'ideal types' and 'repositories'. The former type of boundary objects are typified by diagrams and models that although abstract and decontextualised are sufficiently comprehensible to act as "'good enough' road map[s] for all parties". In this way the business architecture and output based specifications (objects 1 and 2) can be considered as just such ideal types intended to accommodate the routines, needs and preferences of diverse groups, and thereby facilitate the design, procurement and integration of EHR hardware and software. Repositories on the other hand are boundary objects which "are indexed in a standardised fashion [so that] people from different worlds can use or borrow from the pile for their own purposes without having directly to negotiate differences in purpose" (Star and Griesemer 1989, p. 410). The more tangible and concrete objects provided by portals and proto-types (objects 3 and 4) can be considered in these terms in so far as their purpose was to facilitate the coordination of care across organisational boundaries and different clinical specialisations.

We used longitudinal analyses of our documentary and interview data to explore how far and in what ways the putative boundary objects were implicated in the development of the projects as mechanisms for eliciting and incorporating feedback and generating and maintaining the engagement of potential users and others in each case. In so doing we were concerned to identify what role, if any, the boundary object in question had in creating joint fields of practice in which they provided a basis for mutual sense-making, shared understanding and learning. Further, we also sought to identify whether the boundary objects could be construed as doing infrastructural work that supported or provided a generative mechanism for infrastructuralisation in each case.

To aid the reader Table 1 provides more details of the boundary objects and our findings in relation to the infrastructural work that they were able or unable to support.

4 The Infrastructural work of boundary objects in building EHR information systems

We now explore the findings from our analysis. We begin by examining the role of boundary objects in the two national projects and then turn to the two regional examples. As we will see, the boundary objects in the national projects did not, in the main, do work that supported a resolution, or at least a means for managing, global/local tensions. In fact, in both instances they exacerbated such tensions to the extent that the systems were eventually scaled back and/or abandoned. In contrast, the boundary objects deployed in the regional cases proved more effective in supporting, at least in a putative sense, infrastructuralisation by providing a means

through which local actors could make sense of and negotiate solutions to come up with, in one case, a working system, and in the other a prototype to support future national level developments.

4.1 Object 1: A business architecture for a national EHR system in Australia.

In 2000 the Australian Federal government launched Health*Connect*, Australia's first attempt to build a national health information network. This involved the development of a project related artefact in the form of a business architecture (BA) (Health*Connect* 2002a). We focus on the development of successive versions of this artifact, which was intended to be a functional blueprint of the network, designed to answer the question: "what does the facility/system need to be able to do?" (Health*Connect* 2002a, p. 13-14) In terms of the definition of a boundary object, it was, potentially at least, a developing roadmap, created through consultation with stakeholders, that would guide system design and implementation. The first version of the BA was drafted by bureaucrats working in the Federal government department of health and submitted to a 15-member architecture working group comprised of clinicians, health bureaucrats, academics, a consumer representative and health informaticians. This group"s task was to "socialise" it (Policy advisor) and "get it to a point where it is acceptable for public consumption" (Health informatician and member of architecture working group). As a result, a revised draft, *BA* (version 0.7) (Health*Connect* 2002a) was released to the public in March 2002. It was sent to more than 300 organisations and more than 270 people attended follow-up information sessions held across Australia (Health*Connect* 2002b). Written submissions were also invited and were received from a range of individuals and groups including privacy advocates, consumer groups and others. For reasons of space and direct relevance to the mediating role of the *BA* as a boundary object we focus here on feedback from healthcare providers.

In this first round of comments on the *BA*, and in subsequent rounds, there were repeated statements to the effect that the architecture did not take sufficient note of the nature and complexity of healthcare work. For example, responding to *BA* (version 0.7), one of the peak organisations representing nurses in Australia stated baldly that, "the current draft does not acknowledge or respond to the way that nurses work" (Australian Nursing Federation 2002). Similarly another nursing body reiterated these arguments, commenting further that, "if nurses are expected to buy-in to Health*Connect*, then nursing must have its interests heard" and that recognition must be given to the fact that "nursing care and nursing language are fundamentally different from that of other health practitioners" (Royal College of Nursing Australia 2002). Both body's submissions recommended an audit of existing technologies, practices and skills, "to gain an understanding of current technology infrastructure and climate, to minimise incompatibility issues and reduce doubling up of record keeping by nurses" (Royal College of Nursing Australia 2002). A submission by a state body representing general practitioners raised several contingencies that, in its view, needed to be taken into account if the system were going to work. As well as the cost of equipment, it was concerned about the extra time, training and other resources needed, such as a private area to sign up patients (Queensland Division of General Practice 2002). Like the nursing organisations, the GP group recommended more attention

be paid to ensuring Health*Connect* supported the existing practices of healthcare practitioners (Queensland Division of General Practice 2002).

A revised BA (version 1.0) was published in April 2003 (Health*Connect* 2003). Despite the responses to earlier versions it continued to present the Health*Connect* system as a series of abstract and de-contextualised processes and functions. The document was released along with a raft of other reports, and forums for dissemination and elicitation of feedback were organised. A consulting firm was employed to analyse, summarise and report on feedback received (DH4 Pty Ltd, 2004). Again, respondents claimed that the utility of the proposed system was compromised because of a lack of genuine engagement with potential users (DH4 Pty Ltd 2004, p. 18). It was clear that the abstract nature of the architectures made it difficult for individuals to provide specific feedback. The consultants reported that a typical response to their question: "is the proposed structure for Health*Connect* appropriate?" was, "the information is so general that no useful comment can be made" (DH4 Pty Ltd 2004, p. 25). The consultant's report also summarised feedback received about the consultative process itself. The authors identified several shortcomings that highlighted the lack of effective conduits through which user feedback could actually influence the nature of the systems being developed suggesting, "significant groups of stakeholders (particularly nurses and allied health workers) feel disengaged from the consultation process and are seeking much greater consideration of their needs and interests" (DH4 Pty Ltd 2004, p. 31).

A third version (version 1.9) of the *BA* was released in November 2004 (Health*Connect* 2004). This version provided more detail about consent rules, identification and authentication of users, and the implications of the system for work practices. Again, interested parties were invited to give feedback. The plan at the time was to assess the comments received and produce a final version of the architecture—*BA* (version 2.0)—that would be used for procurement and implementation. As far as we can ascertain, version 2.0 never appeared. Instead, Health*Connect* began to unravel. Preparations for implementation revealed how much work still needed to be done (Fujitsu Consulting 2004; Health*Connect* 2005). Similarly, feedback from healthcare providers continued to raise new contingencies such as how data entry, workflows and the form of system reports would work in general practices (General Practice Computing Group, 2005). These and many other detailed issues, stakeholders and others argued, needed to be addressed before any future implementation could be initiated.

Although concerted efforts were made to inform and consult stakeholders through the various versions of the BA, the system for many users in healthcare still remained distant, abstract and incomplete (Fujitsu Consulting 2004). Obtaining productive engagement with potential users around the business architecture was only one of many challenges facing the Health*Connect* project managers. Federal government politicians also grew increasingly impatient with delays and scaled-back the project before quietly abandoning the idea as they searched for alternative options. Significantly, notwithstanding the experience of Health*Connect*, the option that eventually emerged—an initiative to develop a national personally controlled health record—was also embodied in a pre-designed concept of operations that encountered similar resistance and which to date has had little impact on the way health information is shared in practice (see McLoughlin et al. 2017).

4.2 Object 2: Output based specifications for a national system in England.

In England, as in Australia, attempts to develop a national EHR also date from the early 2000s. Within the English National Health Service (NHS) this was eventually manifested in the idea of a nationally available summary care record to be developed as a core component of the National Program for Information Technology (NPfIT) (Brennan 2005; Currie and Guah 2007; Currie 2014). During the 1990s and early 2000s, uptake of digital technologies to share information in the English NHS was slow and sporadic (Wanless 2002). However, in the early 2000s, a series of policy documents argued that progress towards national connectivity could be expedited if expenditure on information systems in the NHS was doubled, and control over design, procurement and delivery centralized nationally; e.g.; (Department of Health 2002a, 2002b). As a result, it was decided to replace all existing information systems in the English NHS with new centrally procured and interconnected systems—a deliberate politically sanctioned policy of "rip and replace" (Senior member of NPfIT).

We focus on the development of an *Output Based Specifications* (*OBS*) that was intended to help manage the procurement process at the core of the NPfIT project, and in particular to communicate the clinical requirement for interconnected systems to vendors in order to enable contracts to be placed and in turn systems to be developed and implemented to the specification. The intention was that the *OBS* would capture the technical specifications of the systems required so that vendors could be contracted to build, supply and in some cases operate the resulting information infrastructure. Two aspects of the *OBS* as a boundary object are relevant for our analysis— its capacity to integrate knowledge from the healthcare and informatics sectors, and its use in managing relationships between the NHS and vendors. Like the Health*Connect* architectures, the specifications were "intentionally generic" and "largely independent of organisational structures" (Department of Health 2002b, p. 20)—and in terms of the definition of boundary objects were another example of an ideal type intended to guide the parties to the project. They were initially drafted out of pre-existing recommendations, plans and specifications arising from previous health information system projects in the NHS (Project member). Draft specifications for what was then called an 'integrated care records service' were circulated to stakeholders and interested parties and feedback received from clinicians and other healthcare providers. Following these consultations revised versions of the *OBS* were completed in a rapid cycle from May to August 2003. They set out hundreds of requirements and potential suppliers were invited to demonstrate how they would fulfill these. The ensuing contracting process was equally swift, and completed by February 2004 (National Audit Office 2008).

It subsequently emerged that there was considerable disagreement about the quality of the specifications and the nature and adequacy of the consultations that occurred around them. For example, an executive director of the entity that at the time was in charge of national health information system development, claimed in hindsight that the specifications were written in "systems speak" and were not fit for purpose. Moreover, "the involvement of clinicians" in their drafting and production was, "by any credible measure inadequate" for a project with such an "enormous scope" and "far reaching consequences" (Nowlan 2006, p. 31). Many observers also

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claimed that the timetable was too rushed and that the consultation for effective requirements capture was inadequate (Brooks 2007; Collins 2004; Hendy et al. 2005).

However, our interviews with project insiders suggested that at the outset many stakeholders were enthusiastic about the project and confident concerning its chances of success. One interviewee, who had been involved in earlier disappointing information system projects within the NHS, thought that "this one is really going to work. [..]. we've got political will, we've got lots of money and we've got a strategy". A senior member of the project team pointed out that the OBS was built on "a huge amount of work, re-work and further re-work across the NHS" and had been able "to consolidate and rationalise" existing knowledge "on the basis of work that had already been done and reinterpret it in the sense of what was needed in the future" (Senior project team member). From the perspective of these interviewees, problems with the OBS only emerged later after contracts had been placed with suppliers at which point "all the people who had been involved were suddenly completely disenfranchised" and had "any aspect of choice" taken away (Senior project team member). In the face of an ensuing "lack of ownership" on the part of clinicians and other stakeholders, initial optimism faded and the project turned out to be, "the worst one of the lot" (Chief information officer).

For example, hospitals charged with implementing the systems found that they had to change the original specifications fixed by the OBS in order to make the systems provided by suppliers work in practice and several contractors left or had their contracts terminated after lengthy legal battles (House of Commons Health Committee 2007; House of Commons Public Accounts Committee 2007). According to evidence given to a parliamentary committee one of the terminated companies, "had received a total of 650 change requests" to the requirements of hospitals not specified in the OBS (House of Commons 2009, p. 12). Whilst the Department of Health claimed that, "most of what [the company] considers to be new requirements were in fact remedial and necessary to make the product fit-for-purpose for the NHS" (House of Commons 2009:12), the fact that these change requests had arisen might be seen as a negative consequence of the rigidity of the OBS itself. Whilst the attempt to hardwire specifications in an output based form was effective in supporting the contracting process in a way that enabled procurement to move rapidly in accordance with the desires of the political and policy sponsors, it meant that subsequent implementation was both slow and costly (National Audit Office 2008, 2011). In 2010, a new coalition government announced that a centralised and national approach was "no longer required" although elements of the system, including the summary care record, were subsequently rolled-out (Currie 2013; 2014; Department of Health 2010; Hoeksma 2011; NHS 2014).

4.3 Object 3: A web-based interface for connecting regional healthcare providers in regional Australia.

In 2000 a consortium of healthcare organisations in a region of Australia obtained Federal government funding for a project that would connect and extend existing health information systems, so that GPs could electronically access data about their patients held in local hospitals. The primary project deliverable, and the boundary object around which engagement occurred was, "an interface based on web-technology" intended to "enable GPs to access hospital infor-

mation on patients in their care, with sufficient speed as to make its use feasible in short patient consultations" (Australian regional project final report). In terms of the definition of boundary objects the web interface or gateway can be regarded as a repository since it was intended to facilitate the co-ordination of care by different clinical groups by making data more readily available to use for different purposes.

The project was managed by a team comprised of medical professionals in management positions in the participating organisations, and technical experts from the hospitals' medical records and information services. A project coordinator, who proved to be an effective boundary spanner, was also employed. One of the project coordinator's first tasks was to establish a working group of nine self-selected tech-savvy GPs who met five times during the first year. They compiled a wish list of hospital information they would like to access through an electronic interface, and gave feedback to technicians on the usability of prototype versions of the so-called Gateway. The technicians worked with legacy systems that varied considerably in their age and capacity to collect and transfer data. The expertise and assistance of the regional director of information services who, according to his own testimony "pretty well knew what was out there, what was available" (Regional director) was vital to the success of the project.

In some hospital departments, clinicians were initially reluctant to make their data electronically available to GPs. The project coordinator negotiated the professional-to-professional compromises necessary to get information flowing. The Gateway through which this was to be accomplished was tested as a prototype web-interface before it went live and this provided a tangible basis for engaging clinicians who were seeking to increase the sharing of patient information across existing organisational and professional boundaries. The prototype supported the "building up a repertoire between the GPs and the specialist" and over time enabled "agreement about what sort of information" should and should not be exchanged (Project coordinator). At this point GPs had access to about 30% of the data they had initially requested, including microbiology, haematology, biochemistry, serology, radiology and nuclear medicine results, and information about surgical interventions.

The focus of collaboration to enable sharing of these data revolved around the notion of a Gateway, which was not constrained by a pre-ordained set of specifications or an architecture, but rather a flexible and emergent interface guided by the GPs' wish list. The final report on the funded stage of the project revealed the degree to which the infrastructural work was sociomaterial in nature. The report estimated that 70% of the work in the project involved "processes and procedures", such as liaising with stakeholders, promoting the benefits of the system, "managing and coordinating work practice change" and involving GPs and hospital staff in decision-making. The remaining 30% of the workload was devoted to what the report labeled "technical issues" (Australian regional project final report). Subsequently, the regional health authority continued to host the system after the initial funding ceased and more information was added to the Gateway as hospital systems were upgraded. However, the continued operation of the Gateway depended on good relationships between the regional health authority, hospitals and the organisation representing GPs. In 2005 the situation changed. As part of a statewide restructure, the regional health authorities were merged. Without consultation or explanation, a powerful actor in the newly merged entity made what participants in the project characterised as an "odious" (CEO GP organisation) and "devastating" (IT manager) decision to sever the information links between the hospitals and GPs.

4.4 Object 4: A computer-based animator for gathering feedback and informing design developed in regional England

This project was one of 19 regional pilots within an Electronic Record Development and Implementation Programme (ERDIP), administered by the administrative authority that was at the time responsible for information systems in the English NHS (see Brennan 2005). The pilot project which provides our focus was commissioned to provide information for a proposed development and deployment of EHRs for front line care communities at regional level. As such, the main task of the project was to conduct, "a comprehensive and rigorous investigation of [electronic health records] resulting in a systems and operational architecture which has been tested and validated against the policies and interests of all user communities and stakeholders" (Internal document).

The objects and processes used to develop this architecture were markedly different to those used in the Australian national case. Unlike their counterparts in Australia, the healthcare providers who participated in the English regional project were not confronted with an abstract draft architecture at the outset. Instead, ethnographic studies of healthcare work that observed how doctors and nurses generated, stored, used and shared information in the course of their normal activities were conducted. Based on these observations, technicians and clinicians in the project team developed a 15-minute computer-based animated demonstration which showed how an EHR could be used to improve the care of an imaginary patient admitted to hospital while suffering chest pains. The *computer-based animator* enabled the depiction in prototype form of how an EHR would work in a particular episode of care—for example an emergency admission to hospital of an older person with several co-morbidities involving the need to exchange data along a pathway covering primary care through to different hospital specialists and subsequently post hospital care. In terms of the definition of a boundary object the animator acted as a repository on two levels. First it simulated the workings of an EHR by showing how different parties along the care pathway could use data for different purposes and second by providing a tool for co-design as the prototype EHR and proposed care environment could be modified and re-shaped to suit the different purposes of clinicians.

For example, the animated EHR was shown to 10 focus groups comprised of patients and healthcare providers to elicit their feedback, on both prospective use of the EHR in care pathways and the animator itself as a tool for engaging potential users through a process of co-design. Attendees were surveyed afterwards and said that they found the animator realistic and useful for conveying information and provoking discussion. As one of the information systems experts leading the project observed, the animator had immediate generative benefits in relation to thinking differently about what a record was:

> There was still this problem with having got the clinical engagement, and it was really quite surprising how strong the clinical engagement was, because in doing this I could almost relate what was going on in the screen with what was going on in terms of care conversations., and we introduced this concept of the joint act of publication. This is not just a record system, this is a publication space. That changed their argument from access

> control—'my stuff, your stuff'—to a 'what do we need to say to each other' conversation (Project member).

Similarly, the focus group participants were also able to identify and articulate the complexities and interdependencies that would need to be addressed if a health information infrastructure such as that depicted during the project were to work in practice. For example, healthcare professionals recognised that the EHR could impact their workloads both positively (less duplication of data entry) and negatively (extra on-going documentation of consent, pressure on clinicians to supply data to the EHR and search it for additional relevant information). While an increased capacity to share information along care pathways was welcomed, there were concerns about the medical data being accessed outside of the healthcare system, for example by social care professionals and organisations.

One upshot of this was a new way of thinking about an electronic record. The animator provided a tangible material way in which the relationship between an EHR and clinical practice could be explored and experimented with. In this sense the animator acted as a mirror which could be held up to examine and reflect upon clinical work routines whilst also providing a window into the work of and experience of others. This facilitated new sense making and the creation of shared understandings within the project and its participants. For example, an innovative view emerged that an EHR should not be seen as a static database but instead as a live, evolving record of the patient as (s)he moved through the care pathway and as different specialists added to the record as a side effect and consequence of their acts and conversations of care with the patient.

After two years of research and development, the project team produced a reference architecture based on principles of federation rather than centralisation of data and intended to inform the development of the proposed national EHR infrastructure. Significantly, this architecture did not propose a specific design. Instead, it provided, "a framework within which ... designs can be defined and evaluated" for local, intermediate and national level services (English regional project reference architecture). It also suggested that legacy systems, rather than being seen as problematic or something to be swept aside, should be retained to reduce costs and the amount of (re-) training needed. The final report of the project emphasised that project managers should "involve stakeholders early" in a "two-way process" to establish a "common view" of requirements and that appropriate financial and project resources would need to support a high level of ongoing engagement (English regional project output document).

However, these recommendations fell on deaf ears. During the final stages of this and the other 19 development projects, the national health information policy was abruptly altered. Instead of the high engagement, incremental and federated approach advocated by the North East England project team, the new national program (as we noted above) deliberately sought to avoid the potential constraints and perceived barriers of the installed base of poorly connected legacy information systems, by seeking to replace them entirely. According to some of our interview informants, selected aspects of the work did find their way into the *OBS* that defined the procurement process for the NPfIT. However, the overall development approach, along with its flexible boundary objects and commitment to user engagement through co-design was, as we saw above, superseded by a preference for top down methods.

5 Discussion: Boundary objects and infrastructural work

The core argument of this paper is that boundary objects, construed as a series of sociomaterial practices, can be more or less supportive of the generativity identified in previous research as underpinning the development of information infrastructures. As noted above, generative mechanisms involve *innovation, adoption and scaling*. Together, these provide novel technical solutions which users are increasingly encouraged to adopt, thereby enhancing the utility to others and providing a basis for the infrastructure to scale by attracting new partners and collaborations (Henfridsson and Bygstad 2013). Our findings indicate ways in which the work of boundary objects, when viewed through a sociomaterial lens, both frustrated and to some extent provided some basis for infrastructuralisation.

First, in the regional cases there are indications that the boundary objects concerned supported boundary spanning activities that acted as *innovation mechanisms*. The web portal in the Australian regional project required clinicians to consider and negotiate the kinds information that could be productively shared between GPs and hospital doctors. In the English regional case insights arising from the use of the animator in co-design led to a rethinking of assumptions that the EHR was a static database. Instead, potential users saw it as a byproduct of the live conversations between care providers and recipients that lay at the core of clinical practice. In both cases the tangible, flexible and malleable properties of the portal and animator as repositories meant they could be understood and assimilated more readily into their sociomaterial practices by clinicians.

In this way the boundary objects in the two regional projects provided links to and possibilities for integration with existing work routines and practices and thereby provided an adoptive mechanism that supported broader take up and use. For example, in the regional Australian case, boundary spanning work ensured high levels of connectivity with existing systems and legacy arrangements which, along with the availability of relevant technical expertise and productive professional relationships between clinicians, meant that take up and use by GP practices and hospitals in the region was readily facilitated. In the English regional case the clinicians engaged in the project and participants in the focus groups felt that thinking of an electronic record as a byproduct of existing care practices meant that they could more readily trust the quality, reliability and provenance of the information it contained. In principle, a system designed to gather data as a byproduct of real relationships would be more likely to be adopted by clinicians for whom the provenance of data is paramount, than repositories of decontextualised data collected and input by a range of unknown clinical and non-clinical actors.

In contrast, in the case of the two national projects, the putative boundary objects that were deployed proved a more mixed and ultimately ineffective means of creating a space for mutual sense making and shared learning to support innovation. The top down nature of these projects meant that there was little scope for productive engagement with users, in particular clinicians, over and above sporadic consultation exercises. The boundary objects deployed were therefore ideal types which had embedded within them largely fixed designs in the form of detailed clinical requirements and technical specifications to meet them. As such it was problematic for clinicians consulted in both projects to envisage or accept that the systems being presented to

them would be relevant to or capable of being assimilated within their sociomaterial practices. In fact, the intentions of those who had initiated both of these objects, consistent with the top down one size fits all approach to system development, was to use the depiction of business architectures and output specification to impose standardised ways of working with and using the systems concerned. As such the boundary objects concerned failed to provide an adoptive mechanism for their take up and use.

Second, the boundary objects in the two national projects proved far less effective as a means of supporting coordination and collaboration with clinical end users. In the case of the Health-*Connect BA* doctor and nurse representatives and others repeatedly suggested in the various rounds of consultation that the system architecture needed to be based on empirical investigations of healthcare work routines *in situ*, so that the system could be designed to support and be useful to clinicians at the point of care. In the case of the NPfIT, the OBS as an ideal type object was seen only as a means of delivering entirely new systems as part of a deliberate rip and replace approach to procurement. The intention here was to avoid problems of connecting to legacy systems on the assumption that there was no need to accommodate the constraints of the existing installed base including the needs and views of clinicians.

Finally, in all four cases the boundary objects struggled in varying degrees to provide the basis for a mechanism that would allow the *scaling* of information infrastructures and evolve from the bottom-up. In the regional Australian case, whilst the project was small enough to enable ongoing face-to-face engagement and collaboration among interested and implicated parties, it did not evolve, "organically through strategies of cultivation" from the existing base (Grisot and Vassilakpoulou 2013, p. 71). The project was unable to bootstrap beyond its regional locale and whilst the system had been designed initially for direct usefulness it failed to gain sufficient momentum to resist or avoid its untimely demise at the hands of broader political forces. The English regional project suffered a similar fate. Those involved in the project fully recognised the complexity of the boundaries across which they were working and considerable effort was devoted to translating, transforming and integrating knowledge from the domains of healthcare, informatics and information governance. In other circumstances the final output from the project—a reference architecture—could possibly have become an effective object supporting the scaling these lessons to a national level as originally intended by the national demonstration programme of which the project was a key part. Nevertheless, within these limitations, in both cases the boundary objects acted as effective repositories allowing diverse actors, at least at a local level to agree and collaborate in using health data for their different purposes.

Problems concerning scaling were though most evident in the two national projects where the two boundary objects as ideal types were intended to provide top down standards which would enable a system to be developed and implemented at local level across the jurisdictions concerned. However, the Health*Connect BA* and NPfIT *OBS* did not do the work necessary to provide a generative mechanism for taking the action in the project forward in this way. In the former case the BA remained an abstract entity and but for the exception of some local pilot trials, the system never made it off the drawing board. In the latter case, despite some initial enthusiasm and success in standardising system procurement the approach ultimately proved a largely ineffective means of implementing a system at scale across the English NHS. Ultimately, significant elements of the procurement were either abandoned before they became operational

or, if implemented, failed to work as specified leaving clinicians and hospitals with considerable challenges in making these elements of the system fit for their purposes.

6 Conclusion

Our aim in this article, following the prompt offered by Star (2010), has been to link the concept of infrastructural boundary objects to the emerging idea of viewing information systems as infrastructures and to respond to calls to examine in more comparative ways the different types of objects used to elicit feedback from potential users and other stakeholders in health information system projects. As Star and Ruhleder (1996) note, "*an infrastructure occurs when the tension between local and global is resolved*" (original emphasis) (Star and Ruhleder 1996:114). Our understanding of the concept of boundary objects implicated in resolving such tensions is consistent with that recently proposed by Doolin and McLeod, that is as a sociomaterial phenomenon that is constituted by both material (structural) and relational (social) properties.

Conceptualised in this way we suggest that boundary objects can play crucial roles in infrastructuralisation by facilitating joint fields of practice in which interested stakeholders bring local knowledge to bear in taking forward the development of systems that aspire towards the global. We have suggested that the potential role of boundary objects in taking the action in information system project forward can also be associated with what have been termed the generative mechanisms essential for infrastructuralisation to take place, Such mechanisms are defined by Henfridsson and Bygstad as "causal structures that generate observable events" (2013, p. 911) and in this sense can also be regarded as seeking to conceptualise the factors in a situation which carry the action forward, in particular in seeking to find ways of spanning the local and the global. However, as Henfridsson and Bygstad note, the causality implicit in the idea of generative mechanisms is contingent (2013, p. 908). Our proposition is that one such contingency is the way in which boundary objects are enacted in efforts to create sufficient shared understandings about the project to enable the action to move forward. In this sense boundary objects can be seen as the sociomaterial means through which causes and effects in generative mechanisms are performed and constituted.

As we have attempted to show in our cases, the boundary objects concerned played a significant role in shaping the trajectory of the action which unfolded in each project. Moreover, the form of the boundary objects themselves—either repository or ideal type—seemed to influence the extent to which the tension between the local and global was resolved, or at least better managed. Accordingly, the objects in the four cases experience mixed fortunes in whether they were able to able to take the projects forward by transitioning from a putative state to being boundary objects in-action. The boundary objects in the two national projects—which we have suggested were examples of ideal-types—were the instantiations of top down attempts to specify EHR systems in a rigid and standardised way to guide subsequent procurement and implementation. This approach severely constrained the development of joint fields of practice that could link the local to the global and alienated key user groups, clinicians in particular. In short both approaches deployed installed base hostile objects (Hanseth et al. 1996). In contrast, the boundary objects in the two regional cases—which we have suggested were examples of

repositories—were more able to do work that provided and supported generative mechanisms in taking the projects forward. The joint fields of practice which they created engaged clinicians and other key stakeholders in bottom-up innovation and adoption to allow, on the one hand, a working system to be produced which linked health records in secondary and primary care, and on the other, significant progress was made in rethinking the health record and its relationship to clinical practice. However, this said, in both cases the boundary objects concerned did not enable the systems to scale beyond their immediate environment.

An infrastructural approach to information systems design suggests that neither top down control through *a priori* design nor ad hoc deals and fragmentation resulting from bottom-up and open-architecture innovation provide a means through which health information systems might continue to develop in a more infrastructural manner (Ciborra 2001; Hanseth and Lyytinen 2010). We agree with this observation but suggest further research is required to explore the nature of the alternative to these two approaches. This alternative would allow both the necessary scope for design-in-use in local joint fields of practice but, vitally in the context of healthcare, support the sharing and exchange of information in a safe, trusted and governable way. Moreover, as Martin (2014) argues, developing such an environment cannot be an outcome of a standard systems design process that aims to identify, select and implement such arrangements in the form of structural resources. Rather, the approach must allow such an environment to emerge as a result of"on-going innovation, diffusion and evolution" (Martin 2014, p. 17). The idea of generative mechanisms is a useful one in seeking to understand how this might be facilitated and achieved. We have sought to make a case for augmenting this line of thinking through the concept of boundary objects, thought of in sociomaterial terms, which we suggest can further help understand the infrastructural work required to take the action in information system projects in a manner consistent with the notion of strategies of cultivation from the existing base (Grisot and Vassilakpoulou 2013, p. 71).

Acknowledgements

The authors acknowledge the support of the Australian Research Council (DPDP110100084) and the interviewees in Australia and the UK who contributed to the research on which this article is based. We would like to thank SJIS's anonymous reviewers and editors for their constructive and helpful comments on the paper.

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