BUILDING INFORMATION MODELLING AS INNOVATION JOURNEY: BIM EXPERIENCES ON A MAJOR UK HEALTHCARE INFRASTRUCTURE PROJECT

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The evolving digital technologies and emerging practices of Building Information Modelling (BIM) represent an opportunity to transform existing modes of design, construction and operation. This paper discusses empirical findings from an ongoing longitudinal case study of a BIM implementation, specific the transition of BIM from the design office to the site environment and from the design phase to delivery phase. Interviews were conducted with BIM innovators and users working for a large international contractor on a major hospital development project in the United Kingdom. The analysis draws on Van de Ven's model of the 'innovation journey' and the associated analytical categories of; ideas, people, transactions, context and outcomes. Analysis of the development and use of BIM on the project reveals the emergent and dynamic nature of the innovation process as it unfolded over time. Although the accounts of the BIM development bore many similarities with the innovation journey findings, we found suggestions of differences in the areas of 'people' and 'context' where our respondents seems too have created more stable and manageable situation than the innovation journey concept would predict.

KEYWORDS: BIM, innovation journey, hospital

INTRODUCTION

The study of innovation is prominent in the construction management literature with uncontested agreement that more and better innovation is important and necessary with. Slaughter (2000), among others, arguing that "Innovations can form the backbone of a company's strategy" (2000: 2). The importance placed on innovation is further underlined by concerns that construction is less innovative than other industries (Winch, 1998). Koskela & Vrijhoef (2001) point out that construction's productivity and quality are low in comparison to other industries and report that the 'major explanation' for this is a lack of innovation.

Given that the benefits of innovation are uncontested, research has focussed on how best to foster and encourage innovation. An example of this is Peansuapp & Walker's (2006) case studies of ICT implementation by construction contractors. Research of this sort seeks to understand the 'barriers' to innovation highlighting among others lack of management support and some user's personal learning capability. More broadly, Winch (1998) attributes construction's low rate of innovation to structural features of the industry (a project-based complex product system industry with separate and conflicting systems integrators. Gann & Salter (2000) argue that, in light of these challenges, a higher-level enabling infrastructure is necessary to overcome these problems and support innovation.

Although such high-level enabling structures are important and worthy of study (see e.g. Seaden & Manseau, 2001), our approach is to focus on drawing lessons from specific cases of innovation (Flyvbjerg, 2004). In the area of digital construction research, Moum etal (2009) have identified “a growing interest among several research communities in the experiences gained from applying new technologies to practice” (2009: 229-30). The research described in this paper, reflects that interest. It is a case study of a project-centred innovation to develop and implement Building Information Modelling (BIM) technologies for use on a major UK healthcare infrastructure project. Our analysis draws on Van De Ven etal’s (1999) concept of the ‘innovation journey’.

The Innovation Journey

The ‘innovation journey’ is a term used by a group of researchers to encapsulate their findings into a series of studies into the “inherently uncertain and dynamic” processes of making an innovation happen (Van de Ven et al, 1999: 3). The Minnesota Innovation Research Programme (MIRP) consisted of fourteen in-depth, longitudinal case studies of significant innovation projects within American companies and public bodies. The research was undertaken within organisations by thirty researchers over a period of ten years studying and tracking innovations as they happened (Van de Ven et al, 1989).

The MIRP studies challenged ‘traditional’ innovation models in which the innovation are thought to move through a series of stages or phases of development. In these traditional models the innovation process was seen as a series of planned, linear predictable moves from equilibrium to equilibrium stabilised by trial-and-error learning and sense making. The MIRP researchers rejected these models as a way of describing innovations as they found no evidence for up-front strategic planning or linear stages in the innovations they studied. It is significant that these findings were not for small, limited innovations. Each study was of significant changes that met the following criteria (Van de Ven et al, 1999):

1. Consists of a purposeful, concentrated effort to develop and implement a novel idea
2. Is of substantial technical, organizational, and market uncertainty
3. Entails a collective effort of considerable duration
4. Requires greater resources than are held by the people undertaking the effort.

The main analytical focus of the MIRP studies was the ‘incident’ (a major recurrent activity or whenever changes were observed to occur). These incidents were recorded and coded in terms of a set of ‘key constructs’, namely; ideas, people, transaction, context, and outcomes. The summary findings of this analysis (compared with the literature on traditional innovation models is shown in Table 1.

Table 1: Summary findings of the MIRP studies (Van de Ven, 1999)..

Category	Literature implicitly assumes:	But we see this:
Ideas	One invention, operationalised.	Reinvention, proliferation, reimplementation, discarding and termination.
People	An entrepreneur with fixed set of full-time people over time.	Many entrepreneurs, distracted fluidly engaging & disengaging over time in a variety of roles.
Transaction	Fixed network of people/firms working out details of an idea.	Expanding, contracting network or partisan stakeholders who converge & diverge on ideas.
Context	Environment provides opportunities and constraints on innovation processes.	Innovation process creates and constrained by multiple enacted environments.
Outcomes	Final result orientation: A stable new order comes into being.	Final result indeterminate; Many in-process assessments and spinoffs; Integration of new orders with old.

The reasons for adopting the innovation journey concept for the analysis of our research was the resonance between the MIRP findings and our own observations from earlier phases of our research of the emergent, negotiated and non-linear nature of the technology innovation process (Harty, 2008). In the following sections we present some initial findings from our own study of an innovation journey; efforts on the part of members of a construction project team to implement Building Information Modelling (BIM) technologies. We briefly present some background on BIM and a description of the case study before an analysis of the innovation in terms of the MIRP categories presented in Table 1. We conclude with some reflections on the usefulness of the MIRP-based analysis and the extent to which our analysis reflects those of the MIRP.

Building Information Modelling

Building Information Modelling (BIM) is a term used to refer to a family of technologies and related practices used to represent and manage the information used for, and created by, the process of designing, constructing and operating buildings. Aspects of BIM such as computer-aided design and 3D representation along with various forms of electronic communication are well established, even ubiquitous, technologies for any reasonably sized construction project (Whyte, 2002)

Of interest now are attempts to gain further benefits from the possibilities of the technologies to integrate the production, sharing and representation of information to join up the design and construction processes, to re-use the same information down the supply chain and to digitally mediate construction activities. To achieve these broader, more ambitious objectives BIM needs to be more than just the use of these various tools. There are technical challenges of software and data inter-operability as well as the need to create appropriate business and social practices and processes.

This wider view is reflected in recent attempts to define BIM in publications aimed at practice audiences. For example,

"[BIM is] a modelling technology and associated set of processes to produce, communicate and analyse building models" (Eastman et al, 2007: 13).

"BIM is the management of information and the complex relationships between the social and the technical resources that represent the complexity, collaboration and interrelationships of today's organizations and environment. The focus is on managing projects to get the right information to the right place at the right time" (Jernigan, 2007: 23)

These definitions highlight the increasing recognition of the importance of understanding the inter-relations between organisational, social and technological constituents of any given 'BIM system' and also the environment in which it operates.

Given the complexity of this undertaking it is perhaps not surprising that even flagship projects have found it difficult to achieve the vision implied by these definitions.

Specific difficulties include: the significant resource requirements and re-configurations of existing practices they demand; the challenge of capturing new practices developed through project work for subsequent re-use; the lack of a clear market leader or of robust integrated technological solutions to guide technology choices. These problems have been revealed both through attempts to develop and implement such technologies in practice, and through research which has followed and traced these efforts (Harty, 2005; 2007a b). The apparently simple introduction of BIM technologies and, crucially, developing the practices and processes to support them is a significant undertaking. It has implications throughout the design and construction process, and that go beyond a simple adoption of new technologies, requiring considerable change to current ways of working.

Case description

The construction project is combination of new build, demolition and refurbishment work across two London hospitals, with a total value of approximately £1 billion. At the time the interviews were conducted design was complete and construction well progressed with the larger new build hospital in the process of handing over areas of the building for commissioning. Final completion of the construction work is scheduled for 2014. The project was funded through a PFI package and contracted on a design-and-build basis with a multi-national contractor leading the project team. The contractor also has responsibility for the facilities management of the project for thirty years after handover.

The innovation project is the development, adaption and adoption of a range of BIM tools by the main contractor. An earlier phase of the research (Harty, 2008) concentrated on the development of coordinated 3D BIM models and related design tools. This phase is concerned with technologies intended to support 'site' applications of BIM. The significant components are:

- Portable tablet computers (with standard corporate builds plus the specific BIM components that synchronise when the tablet is 'docked').

- Coordinated 3D BIM models (local copies of model files split into floors and/or zones for each building).

- Document management system (DMS: customised, in-house corporate system, accessible over the internet to upload and receive information. Manages the explicit issue of drawings by Document Controllers).

- Site BIM integration database. (externally produced product from a small software vendor. Consists of a 3D model viewer and database functionality to allow attribute metadata to be associated with objects in the model and to use these relationships for display, searching and reporting. A link to the DMS presents latest drawings if model objects are selected. New functional elements implemented as user-completed forms for electronic completion of compliance checklists, progress monitoring and defects.)

Method

The research design is an on-going longitudinal case study undertaken in phases of retrospective data collection. The main empirical method is formal, semi-structured interviews with supplementary document analysis, informal meetings and discussions, observations, and feedback on reports. For the current phase, interviews were conducted with main contractor project staff responsible for oversight, implementation and use of BIM on the project (Design Director(2), Project Manager & Operations Manager(2), Document Manager(2), Quantity Surveyor(2), Compliance Manager(2), BIM Co-ordinator, Design & Compliance Manager, Environmental Manager, Project Information Manager, BIM & 3D CAD Manager.)

Our data collection is not theory-led and was not designed to test MIRP hypotheses or to collect MIRP-friendly data so the analysis adopted in the paper takes an exploratory approach to post-hoc application of the MIRP analytical categories. An subsidiary objective is to shed some light on the process of interpreting retrospective case study data. Many case studies use data of this type. The MIRP studies are rare in respect of the ongoing, embedded, longitudinal access to emerging innovations. It is hoped that applying the MIRP framework to our more modest data will allow some reflection on the data's limitations.

Analysis: The BIM innovation journey

The starting point for the innovation journey for 'site BIM' was the previous use of BIM for design coordination (Harty, 2008). This had given the construction teams a "*great visual diagram*" but also "*information in the background that nobody knew about*". Much of the BIM developments have been ways of exploiting that background information. The remaining sections of the report expand on some aspects of this in terms of the MIRP framework that was outlined in Table 1.

Ideas

a coding of the substantive ideas or strategies that innovation group members use to describe the content of their innovation at a given point in time.

In common with other broad approaches to motivation, and with much of the construction management literature (e.g. Slaughter, 2000), the MIRP researchers saw innovation as the implementation of any idea new to those responsible for it. The process of innovation can then include the creation of ideas or the adoption or recombination of existing ideas into a new setting. The major challenge to previous innovation studies is that rather than innovation consisting of one single idea retained and implemented throughout the innovation process, the MIRP researchers found many, emergent ideas and their, "reinvention, proliferation, reimplementation, discarding and termination."

In our case study, the change from design to construction to design has coincided with a significant change in the idea of what BIM is for. The use of the 3D BIM models was originally intended to be used to produce a coordinated design only.

"*no one knew that back then, this is all served off the back of the work that was done in the early days so our mind set was, we are going to produce a 3D model, we are going to check it for compliance, we are going to clash detect it, we are going to convert it into 2D and then we are going to scrap it.*"

"*the part we've got is a part I never thought we'd have…we didn't have the concept back two or three years ago, which is the database linking, which has been so beneficial now*"

The major shift of idea appears to have been to regard the 3D information as an exploitable resource that can be used to support site operations. Even in retrospect though there appears to have been multiple ideas as to what the nature of that support should entail. So, for example one participant stated that the intention for the tablets was to simply get correct, usable information to site users without any particular exploitation of the data.

"*We've got to the construction stage and we are worried about how bloke at the sharp end is going to get his information so that he knows what he's building. […] My responsibility was making sure or trying to do whatever I could for the man at the sharp end to have the latest correct information.*"

Another idea was that using tablet PCs for monitoring progress and compliance was the driver and the information function arose our of that. In another account the purchase of the software that allowed the 'site BIM' functionality was originally motivated solely to produce electronic handover documentation. These accounts suggest the emergent and dynamic evolution of ideas found in the MIRP studies was also the way in which the BIM tools developed.

What does is appear consistent is the idea that BIM is seen as a set of technologies to manage work and to support and drive a 'right first time' precision engineering approach to construction. BIM (and particularly site BIM) is a way to ensure work is done correctly rather than as the provision of a set of open user tools.

"*So what we're forcing the Construction Managers to do is to actually go down the road of actually double checking and job checking everything they're doing and not just sweeping anything under the carpet." "It's controlling them to do their job because it's got to be done in a certain mode. It can't be done any other way, i.e. it's either yes or no in terms of room compliance.*"

It appears that the implementation of BIM implicitly adopts a phased sequential view of operations in which the use of BIM during the design phase is intended to support the development of a correct and therefore fixable 'final design' that can be presented to construction teams for error-free implementation. This broader idea about the purpose and place of BIM can be seen to have influenced many decisions throughout the process.

People

a coding of the people/groups involved in an incident, the roles and activities they perform at a given point in time.

Any complex innovation requires the recruitment and coordination of a group of people to create facilitate the change. In the MIRP studies, this group (rather than a solo entrepreneur or 'champion' executing a fixed project plan) was best characterised as a network of many stakeholders who engage in and disengage from the innovation process over time. The key classes of people are 'innovation entrepreneurs' who risk delivering the innovation and senior managers or investors (often numerous) who sponsor the innovation and make decisions where needed. "Many entrepreneurs, distracted fluidly engaging & disengaging over time in a variety of roles."

On this project on of the most significant events in the launch and ongoing development of information management on the project explicitly and BIM / 3D CAD in particular was the employing of people with specific objectives and responsibilities in those areas (BIM & 3D CAD Manager, BIM Coordinator, Senior Document Controllers).

These people made up a core team of project office staff who took responsibility for delivering the technology and worked on BIM or related systems more of less full-time.

"*But its took a long time to get it because basically its been [BIM & 3D CAD Manager] who's now on board and really involved with it [BIM Coordinator, software vendor] and myself (Senior Document Controller) getting everything up and running and its, you know, we couldn't devote a serious amount of time to it at the start because we only had a couple of tablets but now everything is kind of flowing, the Directors have really impressed with the tablets and can understand why we spend [money on the project].*"

The decisions to start developing IT systems, combined with employment of specific peoples and the involvement of the sizeable Document Controller teams allowed people to develop roles that included a project-specific IT capacity which supported subsequent developments.

The reference to "Directors" in the previous quotation highlights the importance for this project of the other major group of people identified by the MIRP, namely senior managers. There were a number of project directors who approved and supported the project. Specifically these were project directors who provided resources and approvals for the project independent, and sometimes in spite of, the wider corporate system: "*With this project our director… he's given us the go ahead for us to say right [corporate IT], you can be involved but we are going down the [external vendor] route*"

A more peripheral group of actors also participated in the innovation process. These included those with responsibility for aspects of the construction project (e.g. Compliance Managers) who spent time on the BIM project because they saw it as a way of helping to achieve their business objectives and users who interacted with the innovation with requests, ideas or complaints that influenced the ways in which the innovation progressed. One example of the latter is two people (Environmental Manager, Quantity Surveyor) who requested help in extracting quantities of materials from the building models. These were provided (via querying functionality in the site integration database) but, more importantly, the request provided another idea of what BIM was 'for' and provided evidence of need.

This peripheral group, and the approving Directors, appear to have the characteristics of the fluid network of actors described by the MIRP studies. The core, in some cases full-time, core innovation team seem to have been a more stable, consistent group of people than the MIRP studies anticipate. This may have been due to the relatively short duration plus fairly simple nature of our innovation case study. Tentatively though, this could be a significant difference arising out of the project-based nature of the innovation and the apparent ability on the part of the team to hold this aspect constant.

Transactions

the informal and formal relationships among innovation group members, other firms, and groups involved in the incident.

As previously discussed in the section on 'people', relationships and interactions between group members and other individuals and companies are necessary to coordinate the innovation process. These interactions also shape the innovation journey. The MIRP studies identified a wide range of relationship types from hierarchical to peer relationships and informal agreements to more legal forms. These largely bilateral relationships are also located in (and help to create) a wider network of relationships. An, "expanding, contracting network or partisan stakeholders who converge & diverge on ideas."

The relationships between core team members were not discussed by respondents. In research terms, we would anticipate that following the innovation real time would have revealed numerous interactions that would have had implications for the innovation. Our interviewees did not problematise or remember or simply chose not to talk about these issues. Rather, the salient relationships for innovation team members were between them and more peripheral or external agents. Particularly highlighted are personal relationships between innovation team members and individual software developers and more 'corporate' relationships between the project and the contractor's corporate IT department.

Interviewees have stressed that at times work on the BIM project was 'unofficial' – particularly when developing what amounted to proof-of-concept working prototypes. This made the innovation reliant on personal relationships, vulnerable to prioritisation of official work and they were presumably running at risk of being cancelled at any time. However, there is a clear narrative that the informality and small scale of the development was crucial to the success of the innovation. "*We'd never been in the position we are now had we not had [internal DMS system] on this project. The reason being is 'cause it's developed in-house and we've actually hooked up the [externally produced integration database] programmer with the [internal DMS] Programmer, they can sit down, they've sat in this room many a time and coded out the requirements to get the portability onsite and all the documentation onsite. Had that been something like Documentum (a large DMS provider) and we'd have had to go off to the costs involved and we would never have got to where we've got because the costs would have been a – there would have been an alarm bell ringing in the first instance.*" Our analysis is suggesting that the IT projects had just enough resources to achieve something but few enough that they were able to stay 'under the radar' until they could demonstrate benefits. "*[BIM Coordinator] has done it best part of three years with the [external vendor] guy, living in each other's pockets, getting the system to where it is now*". Key to this, along with the intrinsic interest in working on 'something different', was the personal trusting relationships between innovation team members and developers working sometimes without the knowledge or explicit approval of their parent organisations.

As discussed previously, the BIM implementation on Barts and the London are talked about as a project innovation. The relationship, or rather the negotiated lack of relationship, between the project and the corporate IT department (ITSD) was mentioned frequently. There was some concern that innovation was hampered by ITSD "*this is a perfect bit of software but ITSD have to approve it, it has to go through about a year of test before they say yeah, that's the one*". More broadly, ITSD don't understand what's required on site. "*A lot of the issues we've had with the Tablets is the IT Department set them up to a working format and because they're detached from the site, it's – they need to come out to site more often to actually get… what they need on the site works 'cause they're just stuck back at [head office]*".

Context

a coding of the exogenous events outside of the innovation unit in the larger organization and industry/community that are perceived by innovation group members to affect the innovation.

Context items are those 'outside' the innovation system that either support the innovation process (availability of technology, an industry training scheme, etc.) or hinders it (e.g. lack of finance, regulations). Salient context can range from broad macro features at the level of an economy or industry to micro-level factors located within a specific organisation. The, "innovation process creates and [is] constrained by multiple enacted environments."

In this study, wider contextual issues whether supportive (such as the increasing potential of computers) or constraining (like the perceived computer illiteracy of many construction users) were mentioned but not emphasised by respondents. What seem more significant in explaining what has been framed as a 'project innovation' are a number of project contextual factors that have influenced the development of the tablets and related BIM systems. It seems likely that the idea of the BIM innovation as a project-centred innovation is the reason that wider contextual issues were relatively down-played or taken for granted in the interviews. The project context issues were; scale, complexity, and project organisation.

Scale: One recurrent issue on the current stage of the project is the sheer scale of the projects and the work required to manage them. The largest new-build hospital has a programme of handing over 6,500 rooms to the client. Each handover requires a number of processes including progress monitoring, snagging (faults and damage), compliance (correct equipment installed correctly as confirmed by the client's Independent Tester) and certification. "*You know everyone's got important deadlines to achieve. I mean at the moment, we're trying to do fifty rooms a week to be finished and locked out and that goal is until July of next year*". The sheer volume of work has provided the business case for the partial computerisation of the checking and handover process.

The size of the projects also meant that the simple ability to be able to call up a drawing when out on site has the potential to save significant time just in construction managers walking back to (and getting stuck in) the office. "*Well from one end of the site to the other, you know you waste a good hour, two hours maybe. . . It's absolutely massive, you can get lost in it as well and then getting back to your office, once you get back to your office, once you've been out on the site, you know you've got to sit down and catch up on your e-mails quickly before going back out*".

Complexity: As an acute hospital the project design is also complex, especially in terms of the coordination of the many different services required and between the service, structural and architectural components. Service coordination and clash detection was one of the most important reasons for the use of 3D BIM models in the design phase (Harty, 2008). As discussed in 'ideas' the site BIM development are now seen as a way to ensure this complex design is delivered precisely on site.

Construction management approach: Another project context factor that seem significant from our analysis is the way the main contractor has organised the coordination of the works. The contractor does quite a lot of on-site coordination and supervision on the project (as opposed to a 'construction management' model of allowing trade contractors to manage their own coordination). Skanska construction Managers are responsible for handing over a spatially defined area of floor, across work packages. "*[We break] it down into little packages 'cause we have the expertise, we think, to manage it at a micro level 'cause it's cheaper. . . . So there is, therefore, an element of us acting as the Foreman in the field, … and sometimes these contractors, you know, we're in effect co-ordinating where they work next week,… so having got the Tablets and the information, we then said, "Well these should be used for progress monitoring*". So it appears that in the evolution of tablet functionality, the business strategy to let small packages and get value from expertise in management created a requirement to support progress monitoring.

Outcomes

when incidents provide evidence of results , they are coded as representing either positive, negative, or mixed.

The outcomes of interest during the process of innovation are the interim criteria and subjective assessments that entrepreneurs and managers use to make decisions about approving and directing elements of the innovation journey. MIRP researchers found that the way in which outcomes were evaluated (and specific outcome objectives were set) fluctuated over time – assessment criteria responded to changed priorities and events. The, "final result [is] indeterminate [there are] many in-process assessments and spinoffs [and] integration of new orders with old."

Our respondents did not tend to describe their innovation journey in terms of explicit outcomes. There have been attempts to demonstrate business benefits from the technology use (better control, time savings) but these are still being worked on and in any case do not do not seem to have been part of the interim outcomes that drove the innovation process.

In our data, innovation outcomes are largely implicit – the fact that a piece of software has been made available to users is an outcome in itself. "*So, when I got to a point where we've got a Tablet that delivered the latest information, I was just delighted*". Similarly, after delivery of the technology, another class of outcomes mentioned is the use or adoption by 'users' outside the innovation group. This is viewed as especially positive given the assumed reluctance of builders to use new technology. "*I mean there is one guy that couldn't switch a computer on and now he's a tablet super user, you know, whatever he's doing, he's got his tablet with him so its good to see people like that embracing the technology and understanding what it is so I think you know, a lot has changed in the last three years of this project.*"

From the perspective of innovation group members the other significant 'acceptance' outcome was when project directors approved a stage of the development or made additional funding available as in the following incident in which a team member demonstrates a stage of the development of the tablet PCs and software to the project director to gain agreement to purchase additional tablets:

"*I literally went to him and said, "Right, this is what a floor looks like, this is the room, that's your information, that's your latest C-Sheet, that's your latest room datasheet." "Fantastic. Right, now show me for that room." Dink. "Now go to the fourth floor and the mental health room. So, find the mental health room. Now, that C-Sheet is wrong, isn't it?" And you go – or is it? And you click on it and it was one hit and it was the latest version and he said, "Right, that's fine. I understand. So it works." "Yes, it works,[Project Director]." "Right." You know, and that – so he, kind of, did a little audit of his own and obviously challenged others and then was convinced*".

Accounts of specific events like this are rare in our data – during our largely unstructured and open interviews respondents tended to talks in terms of activities, generalities and descriptions of states. The insights gained from attempting to apply the MIRP incident categories to retrospective data is discussed in the following section.

Discussion

Our discussion will cover the substantive findings in terms of the extent to which our case study data matches the MIRP findings plus some refection on the methodological and analytical issues identified.

The evolution of 'ideas' and the overall innovation process for our BIM case study is well described by the innovation journey concept. Our data also has elements that seem to confirm the importance of 'transactions' required. Our findings are short on 'outcomes' but this is probably due to the research method – the post-hoc nature of the study and that outcomes are largely implicit (also people were perhaps naturally reluctant to highlight negative outcomes). Where there seems to be some variance with the was in the categories of people and context.

The context items identified were not primarily at the macro-level but project-specific. The specific innovation studied appears to have selected (or even made) its own context by being a project rather than corporate innovation. Compared to the innovations studied by the MIRP, our case study is relatively short and of limited scope and complexity. The project-based nature of construction organisations does appear to have been specific though particularly as BIM was seen as a *project* innovation that happened independent of the wider organisation (although a higher-level strategic intention to support and expand BIM does exist).

In terms of people, the MIRP studies would lead you to expect a fluid network of part-time entrepreneurs. In contrast, although a number of peripherally involved people fitted this description, the core innovation team appear to have formed a consistent and stable group for the duration of the innovation period studied. As with the relatively simplified, and more manageable project context, this appears to have been important in maintaining the innovation. Further research over a longer time scale and moving the focus of research 'up' to the contractor's wider efforts to expand BIM usage may reveal a looser more impermanent network along MIRP lines (for example as innovation team members are moved to other construction projects).

Methodologically, applying the MIRP categories to our data highlighted the difficulties of constructing precise empirical accounts of innovations from retrospective interview data. As already described, our data collection was not designed to test MIRP findings or elicit data in terms of MIRP categories and this resulted in 'missing' data. For example, the MIRP analysis was focussed around the 'incident'. It became notable that our respondents did not generally talk in terms of specific incidents or events but rather in terms of broad narratives and statements about steady states or 'how things are'. Data was also not spread evenly across

MIRP categories (there was very little discussion of ‘outcomes for example). We anticipate following up some of the gaps identified in further research.

Finally, as a coding framework, the MIRP categories were not exclusive and highly dependent on where the analyst draws boundaries. A director approval from outside the project could be people (making the director part of the innovation team), transaction, context or outcome. The presence of project Document Controllers available to provide IT support could equally be coded as ‘context’ rather than ‘people’. Other research that attempted to use MIRP categories for more rigorously empirical forms of analysis such as content analysis would need to pay attention to this issue.

CONCLUSIONS

The BIM innovation journey demonstrated many of the significant features of those studied MIRP, particularly the non-linear nature of the process, the emergent nature of the ‘ideas’ and the importance of a range of different ‘transactions’. However, the project-based nature of the innovation seems to have allowed the innovation team to have limited the complexity and turbulence of ‘people’ and ‘context’.

Comparison of retrospective case study data with MIRP findings highlights limitations of the former that can guide further research or strengthen subsequent analysis.

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