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Advancing social practice understandings of digital innovation delivery in construction project management

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Abstract:	

Advancing social practice understandings of digital innovation delivery in construction project management

Abstract

Purpose

The paper applies social practice theory to clarify the process of innovation design and delivery from one successful digital innovation: the BIM risk library. The paper clarifies the practices surrounding construction innovation and provides a schema useful for practitioners and technology designers through a social practice analysis.

Design/methodology/approach

The paper applies Schatzki`s 'organisation of practice' concepts to a construction project innovation to clarify how the practice of innovation revolves around understandings, rules and teleoaffectivities (emotive behaviours). Sources for the study include notes from meetings, workshops with experts and the shared artefacts of innovation.

Findings

The practice of innovation design and delivery are clarified through a social practice analysis: a distinct "field of practice" and a "schema" of generalizable prescriptions and preferences for innovation delivery being presented.

Originality

The social practice analysis of one successful construction innovation is an original contribution to the body of knowledge, adding a level of detail regarding innovation design and delivery often missing from reported research.

Practical implications

The paper informs the practice and process of innovation design and delivery; the insights clarify how collective understandings and rules of use evolve over time, becoming formalized into contracts, agreements and workplans. Practically, processes whereby innovation 'sayings' evolve into innovation 'doings' are clarified: a schema detailing prescriptions and preferences of practitioners and developers being presented.

Keywords: innovation studies; BIM; building information modelling; digitalisation; projects-as-practice; social practices; health and safety; data engineering.

Introduction

Managing an innovation is as important as the innovation development process itself (Bamel et al. 2023); construction project management innovations being interventions into existing complex working practices (Liu et al. 2018). As such, aligning an innovation to those practices to minimise disruption and continue business-as-usual processes is important. Additionally, the process of innovation adoption whereby an innovation becomes part of everyday project-based working practice remains unclear: innovation adoption being a complex business, with little to guide practitioners through the messy and contingent process of adoption and diffusion (Harty, 2005). Therefore, understanding how innovations are delivered is important for improving innovation practice itself (Havenid et al. 2019). Whilst Winch (1998) notes that more case studies of trajectories of innovation are required in order to identify who generates new ideas and how they are managed into "good currency", the process of innovation design, prototyping, testing and deployment requires a theoretical and conceptual unpacking using empirical evidence. This paper makes a contribution by examining how one successful digital innovation was developed and deployed with several project-based organizations to become part of their everyday working practices. The innovation (the BIM Risk Library) was recipient of several industry awards (buildingSMART, 2020; Construction Computing Award, 2021) and therefore provides valid data regarding a "successful innovation". Amongst the key questions posed by the paper are: what contributes to successful innovation deployment in construction project management? What are the drivers and inhibitors of successful innovation delivery? How can the innovation delivery process be conceptualised and understood?

The paper adopts a projects-as-practice (Blomquist et al. 2010) approach and uses social practice theory (Schatzki, 2001) to review the process of innovation delivery. The case for adopting a projects-as-practice approach for understanding what occurs on projects has been made for some time (c.f. Koch et al. 2019; Blomquist et al., 2010; Clegg et al. 2018). In outlining a projects-as-practice approach to conducting research in project management, Blomquist et al. (2010) note that project management is an immature field of research, where many of the normative and traditional contributions are insubstantial when it comes to understanding what is really occurring in projects (see Winter et al. 2006). Clegg et al. (2018) argue that practice-based research provides a methodological lens to explore the reality of project management work; the authors noting that practice-based perspectives are under-represented in project portfolio management (PPM) research, whilst presenting an agenda for further practice-based research, including its discursivity, representation, dynamic capabilities, leadership and materiality. This paper follows this tradition by employing a "social practice" theoretical perspective to established frameworks for innovation diffusion; the framework of Steiber and Alänge (2015) being a foundation upon which a social practice analysis of processes and interactions may be overlaid.

The paper adopts a granular analysis of the interactions between innovation stakeholders to identify the concepts characterizing a 'practice of innovation delivery' that pivot around rules, understandings and teleoaffectivities (emotive behaviours). The analysis of the work around one successful digital innovation (the BIM Risk Library) leads to identification of specifiable enacted schemas (i.e. practitioner preferences and generalizable procedures) to be addressed by innovation developers. As a result, the practice of innovation delivery in construction contexts is noted to be distinctive and governed by specifiable preferences and prescriptions (Knorr Cetina, 2001): understanding construction working practices and aligning an innovation to those practices being critical for successful innovation design and deployment. The originality of the work arises from the analysis of each step of the innovation design and delivery process and its' associated artefacts using Schatzki's practice theory concepts. The contributions which result, around sayings, formalisations, doings and a schema for innovation delivery add to the body of knowledge concerning construction project innovation.

The paper is organised as follows. A literature review scopes out understandings of the practice of innovation delivery in construction, identifying gaps in knowledge and issues requiring clarifications. The projects-as-practice literature and social practice theory of Theodore Schatzki are then presented to provide theoretical orientation and foundation. A methodology section describing the research approach adopted is followed by presentation of the innovation: the BIM risk library: a collaboration between University of Manchester (UK), the UK regulator for workplace health and safety (the Health and Safety Executive – HSE), several construction companies and a building information modelling (BIM) software provider. The high-level review of innovation development work is complimented by deeper analysis of the collaborative agreements between partner organizations and data management workflow employed for innovation data harvesting and development. Collectively, this evidence distils the 'field of practice' (Schatzki, 1996) of innovation delivery in construction with an "enacted schema" for innovation delivery coming into focus from the analysis. A following discussion notes how the social practice findings align and enhance the framework of innovation diffusion of Steiber and Alänge (2015): innovation evolution being understood in social practice terms, with a schema for innovation delivery and relations between "sayings", "formalisations" and "doings" being presented. A closing conclusion draws the insights of the paper together.

Understanding the Practice of Innovation Delivery

Recent published work regarding innovation in the construction industry has addressed a variety of subjects, including the effect of supply chain innovation on competitive advantage (Afraz et al. 2021), open innovation and the enhancement of productivity (Greco et al. 2021), innovation ecosystems and collaboration in infrastructure projects (Vosman et al. 2023) and boundary-spanning for managing digital innovation in the AEC sector (Azzouz and Papadonikolaki, 2020). Whilst these contributions have added to the body of knowledge concerning innovations in construction, there remains a need to understand the practice of innovation delivery. In this respect, whilst diffusion of innovations across firms has been recognised as a non-linear process (Shibeika and Harty, 2015), research has also examined how companies organise for digitalization (Morgan, 2019). However, understandings of the practice of innovation delivery are opaque and ambiguous: understanding the trajectory of a digital innovation (Winch, 1998), and how an innovation transforms from research idea to a fully-fledged application being much less understood. It has been noted that the relationship between system developers and potential industry users can be contentious (Liu et al. 2018), with challenges towards industry uptake of innovations being considerable (Oesterreich and Teuteberg, 2016). Whilst technical, practical and social barriers to innovation uptake are commonly evident (Collinge et al. 2020a), Blindenbach and Van Den Ende (2010) note that project-based firms have more difficulty innovating products, services and operations as compared to when they innovate for their clients. As a result, suitable engagement strategies and appropriate working relationships with technology developers need to be established. Blindenbach and Van Den Ende (2010) also note that the effects of specific management practices on project performance are different, particularly the effects of planning, multidisciplinary teams and heavyweight project leaders. The authors note that differences in firm characteristics provide an explanation for the findings; an implication for the innovation management literature being that "best" practices for innovation management are firm dependent. Söderlund (2004) points out that process and real-time case studies and project organization issues are of particular interest, and therefore analysis of exemplar "successful" innovations can provide the empirical data needed for such studies.

Cicmil (2006, p. 36) asserts that project theory would be served by a qualitative approach with a critical interpretive lens that might 'generate alternative understandings of what goes on in project practice and how practitioners participate in and manage complex organizational arrangements.` Consequently, examination of what people do in project contexts is a valid analytical approach rather than a confirmation of best practice models for project management (cf. Geertz, 1973). This aligns with Blomquist et al. (2010), who argue for a practice perspective (Schatzki, Knorr Cetina, & von Savigny, 2001) that begins with individual actions and asks what overall models and concepts result from those actions.

Practice theory has been used to study interactions in construction project management contexts previously, for example to understand digital integration of built-environment practices (Çıdık et al. 2017) and collaboration in construction (Connaughton and Collinge, 2021), but epistemological and ontological uncertainty remains, particularly regarding the delivery of innovations in construction project management. For example, whilst Bresnen (2009) argues that a 'practice' perspective allows us to focus on what happens in actuality: understanding practices being potentially more informative than industry-wide models of ideal processes, Marshall (2014, p.110) notes that practice theorists often fail to provide empirically sound demonstrations of theoretical propositions in action, thus limiting the usefulness of ideas. For example, the practice theory objective to clarify the emergent and ongoing constitution of social orders and change through situated practices has not been substantially engaged with. Similarly, whilst Blomquist et al. (2010) propose a 'project-as-practice' approach for understanding the complexities of working practices occurring in projects, noting the specific challenges for the researcher, O'Keeffe et al. (2015) comment that it is the 'doing' and 'performance' that should be the basis of analysis in practice theories when stating,

'Practice theory refocuses attention on the social nature of organized activities and how these relations are mediated by the materialities within which they become enmeshed.' (p. 416). This paper directly addresses the comments of Marshall (2014) and O'Keeffe et al. (2015) above by providing an empirical demonstration of practice theory concepts in action, and by highlighting the "doing" and "performance" of innovation practice in a construction context.

Whilst the above reflections highlight the importance of empirical evidence for informing theoretical understanding of practices, in terms of models of innovation, important work has already been conducted in the field. Rogers (1995) notes six innovation-characteristics that matter for its diffusion in a social system; these being: its relative advantage for the adopter, its compatibility with the pre-existing system, its complexity or difficulty to learn, its testability, its potential for re-inventions, and its observed effects. Building on the work of Rogers, Steiber and Alänge (2015) present an analytical framework for diffusion of innovations (figure 1). The framework includes five steps that a firm goes through when searching for, adopting, and implementing either a technical or organizational innovation: the five steps being desirability, feasibility, first trial, implementing, and sustaining. These five steps are in turn dependent on a firm's organizational improvement trajectory, which is cumulative and path-dependent due to increased return on investment on existing innovations, as well as on internal inertia among board members, top managers and employees. The five steps are all subject to three sets of influencing factors: characteristics of the innovation, the internal context, and external context (that include diffusion mechanisms).

[Figure 1]

In figure 1, the five steps are visualized as a circular pattern around an organizational improvement trajectory. The framework of Steiber and Alänge (2015) provides a validated model for the digital innovation delivery process by which activities could be analysed or planned. More recently, Steiber et al. (2021) explored the digitization process for industrial firms, presenting a validated framework based on innovation diffusion theories and case study evidence, with inhibitors and drivers of digital transformation being identified. As Steiber et al. (2021) note, diverse theoretical perspectives and new research methodologies are needed in order to understand the major challenges that block or hinder firms` deployment of digital technologies. These insights reveal how there remains a need to understand the practice of innovation in clearer terms.

Social Practice Theory

Theodore Schatzki`s social practice theory (1996; 2002) enables a domain to be examined as a ‘field of practices’ with ever evolving ‘nexuses of doings and sayings’ (Schatzki, 1996). Although Schatzki (2001) notes that practice can refer to both individual performed activities and a guiding principle for activities, Knorr Cetina (2001) observes that the majority of scholars agree with the definition of practices as:

‘recurrent processes governed by specifiable schemata of preferences and prescriptions’ (p.175)

Schatzki`s theory of practice (1996; 2002) is generally considered as one of 5 current approaches to studying practice (other approaches being communities of practice; activity theory; ethnomethodology and discourse analysis: Nicolini, 2012). Nicolini (2012) encourages researchers to draw selectively on concepts from different approaches to illuminate various aspects of practice, proposing a “toolkit approach” for empirical work. Such flexibility makes practice theory a potentially attractive methodological approach, whilst also remaining challenging. As Schatzki (2012) comments, 'The world according to practice theory offers much to investigate. There are practices, arrangements, activities, bundles and constellations. There are questions about which of these exist, when and where, their details, how they work and unfold, how they can be designed or altered, and how to prepare people to enter them.' (p.23)

Schatzki (1996) maintains that practice is a "temporally unfolding and spatially dispersed nexus of doings and sayings, embracing notions of activity and organization" that make up people`s "horizons of intelligibility" (Nicolini, 2012). Caldwell (2012) maintains that Schatzki`s ambition is to ensure practices are ontologically more fundamental than language and discourse: practice actions (the "*doings*") taking priority over practice language (the "*sayings*"). Consequently, Schatzki gravitates toward a concept of agency as "doing", underplaying the role of language and discourse (Schatzki, 2002); in this scheme verbal and non-verbal signs are part of the "doing" of a practice rather than its principal components. Schatzki therefore distances his theory from those of Bourdieu and Giddens by rejecting Bourdieu`s concept of "habitus" and Giddens concept of "practical consciousness" (Caldwell, 2012).

Whilst practice theorists generally maintain the social as a field of embodied, interwoven practices organised around shared practical understandings, the concept of "*field of practice*" or "*site of the social*" (Schatzki 2001) distinguishes Schatzki`s theory from those of others (c.f. O`Keeffe et al., 2015; Nicolini, 2012). This notion can best be described as the *context* within which practices occur: a "fields of practice" analysis being one that: a) develops an account of practices and/or b) treats the field of practice as the place to study the nature and transformation of their subject matter. This ontology comprises an array of orders and arrangements of people, artefacts and entities that constitute the organized activities of that place (Schatzki, 2001): the practices within a context being made explicit to identify the "practice-arrangement bundles" of which those practices are part (O`Keeffe et al. 2015). As Schatzki (2013) states:

'The coalescence of a practice involves some combination of (1) the emergence of common rules (explicit formulations) in the light of which actors proceed, (2) the crystallization of sets of prescribed or acceptable ends, tasks and actions, (3) the development of common practical understandings, and (4) the distillation of common general understandings.' (p.37)

With a social practice approach, examination of the digital innovation experience cannot be understood separately from its` context: that context being a "field of practices" within which the innovation resides. As stated earlier, there is value in clarifying what constitutes a supportive context for delivery of an innovation. Schatzki`s classifies the 'organization of practice' into 4 concepts (Table 1).

[Table 1]

Referring to Table 1, an action belongs to a practice if it expresses one of the understandings, rules or teleoaffective conceptsthat organize that practice, with activities forming a nexus in that they are organised and connect together through such relations as causality and intentional directedness (Schatzki, 2012, p.15). Of the above concepts, teleoaffectivities may be the most difficult to conceptualise. It is best understood by conceding that separate practices possess their own sets of acceptable and enjoined intentions, actions, emotions and moods (Schatzki, 1996, 101). In construction, intentions or goals are often influenced or directed by normative and emotional behaviour (Caldwell, 2012, 290), with certain teleoaffectivities being associated with specific practices. For example, a project team may express surprise and shock at a supplier quote five times above the going rate. Teleoaffectivities are those emotions, moods and actions that become associated with certain practices.

For an innovation, teleoaffectivities (i.e. positive or negative reactions) are potentially significant to the success or failure of the innovation. For example, surprise and joy at being able to perform a task not previously possible would be a positive teleoaffectivity, whereas frustration or confusion about innovation use would be a negative teleoafectivity. Therefore, developers must be aware of teleoaffectivities and build-in processes to ensure possible negative reactions are mitigated. This can be done via engagement activities, workshops and pre-piloting work.

Schatzki (2002) also states that "human agency must be understood as something contained in practices" (i.e. as the performance of doings and sayings that constitute the actions that compose practices" p.240). Similarly to Schatzi, Sewell (1992), a practice theory scholar, understands practices as enacted schemas (i.e. generalizable procedures) that can be transposed from one domain to another, but that also organise and constrain other schemas. This paper takes forward these ideas and Schatzki`s 'organization of practice' concepts to investigate the practice of digital innovation delivery on the BIM Risk Library.

Methodological Approach

Theoretical Positioning

Theoretically, the research may be categorised as "social-science based" and "process-oriented" rather than "engineering-focused" research (see Blomquist et al, 2020, p.6). As a 'theories-in-use' contribution (Söderlund, 2004), the focus on project processes enables a theory and its` associated concepts to be applied and examined objectively. In this case, the paper applies social practice theory and the concepts of Schatzki (Table 1) to understand the process of innovation delivery, such an analysis taking into account the complexities of human life (c.f. Cicmil and Hodgson, 2006, p.10). Such an examination of social processes at work (i.e. how understandings, emotions and rules emerge, evolve and become formalized) addresses the need for more fine-grained studies of the microactivities occurring, as noted by Blomquist et al. (2010, p.7). Methodologically, this paper follows the lead of O'Keeffe et al. (2015) in focusing upon the "doing" or "performance" of innovation, and the processes leading up to such "doings" in a construction project management context.

Practical Details

Practically, in terms of methodological steps, figure 2 presents the overall flowchart of work from the BIM Risk Library project. A series of 'legal artefacts' associated with phases of work activity are also highlighted: these legal artefacts being critical to the mobilisation of the innovation. Methodologically, to conduct a social practice analysis of the work occurring, each separate work activity was examined by the researcher using the 'organization of practices' concepts of Schatzki (1996) (Table 1). This meant identification of how rules, understandings (both practical and general) and teleoaffectivities (emotive behaviours) manifested through spoken dialogue, shared artefacts and plans of action to be taken forward. Sources of data included notes from meetings, the workshops with industry practitioners that captured thoughts and reactions to the innovation by industry experts, and the shared artefacts that played prominent roles in the innovation design and delivery journey (i.e. collaborative agreements; data management workflow; user guide; software tool). The multiple meetings between research team and industry partners were recorded on a Trello board, providing a further source of data. As will be noted, the shared artefacts, such as the collaborative agreements and data workflow formalised how the innovation would operate and function. A post-pilot survey of practitioners and interviews with individuals provided a further source of data for analysis. The researcher examined the data chronologically, in logical order, as noted on the figure 2 flowchart of work activities. Regarding the meetings and workshops with industry, it should be noted that discussions (i.e. spoken words) between stakeholders revolved around the functioning of the innovation, how it should/could be used and how it would potentially impact (positively or negatively) project work practices. Whilst acknowledging that such conversations and 'messy talk' are intrinsically a part of collaboration using BIM (Dossick and Neff, 2011), the focus of analysis was the 'organization of practice' concepts of Schatzki (Table 1) and how and when they manifested. As noted, this manifestation would be through spoken dialogue, shared artefacts and plans of action to be taken forward. Such a microanalysis of processes takes into account the complexities of human life for a practice-oriented study (c.f. Cicmil and Hodgson, 2006, p.10): the deeper examination of interactions also addressing the need for fine-grained studies of the work occurring (Blomquist et al. 2010, p.7). As noted in the following sections, the social practice analysis facilitated clarifications of how 'sayings' transform into 'doings' of innovation delivery and use; the preferences of practitioners leading to a provisional 'schema for innovation' for a construction context.

[Figure 2]

Innovation Analysis

The BIM Risk Library project commenced in 2019 under the Discovering Safety research programme: a collaboration between the Thomas Ashton Institute (TAI, 2020), the University of Manchester and the Health and Safety Executive (HSE), UK regulator of workplace health and safety. Aiming to assist design and construction professionals to better manage health and safety via proactive use of digital technologies and mobilisation of information resources via a Prevention Through Design (PtD) approach (Yuan et al. 2019), research work resulted in a novel BIM-based tool developed within a commercial cloud-based platform (the BIM Risk Library). Four different companies, with a total of six separate construction projects partnered with the research project. Each project agreed to use the innovation, formalizing their commitment via signed collaborative agreements. The projects had an average duration of four months, and ranged in type (i.e. residential; industrial; commercial; infrastructure projects). By way of illustration, a screenshot of the BIM risk library tool is given in figure 3.

[Figure 3]

Separate work activities of the BIM risk library are now examined in sequence, as shown on figure 2.

Steering Committee Formulation

A Steering Committee was setup for the BIM Risk library composed of research project stakeholders. A primary source of membership was the BIM 4 Health and Safety Group (BIM4H&S): a UK industry group focused on digital technologies to improve construction health and safety. This group was instrumental in work leading to the industry standard PAS 1192-6: 2018 'Specification for collaborative sharing and use of structured health and safety information using BIM' (BSI, 2018): a working link with this group therefore being important as the innovation addressed digital technologies to improve construction health and safety. Frequent communication with the Steering Committee membership ensured that both *general understandings* and *practical understandings* of the innovation were discussed openly from an early stage. As research team ideas regarding the innovation evolved, these could be bounced off Steering Committee members; such interactions being an essential social aspect of innovation development. *Rules* around innovation use were also discussed and clarified with industry figures in a collaborative way at meetings. Amongst the questions asked were: how would the innovation impact existing project ways of working? What training and instruction would be provided? And how long would the innovation be mobilised? How could data be drawn from live projects and anonymised? These practical questions were critical for the further development of the innovation. The Steering Committee were consulted are regular intervals through the research project; the link being vital for *understandings* and *rules* of use to emerge.

Ontology and ERIC matrix

A foundational idea of the BIM Risk Library was formulation of an ontology to map out the elements that make up a risk scenario requiring specific treatments: the ontology concepts being rooted in industry guidance and previous academic work in the field. Details of the ontology and matrix are provided in Collinge et al. (2020b). The ontology embodied rules regarding types of data to be collected and the relations between them. Validation of the ontology and matrix came from the Steering Committee and BIM4 H&S group, which again enabled *general understandings* and *practical understandings* regarding the foundational ontology and its` conceptual underpinning to be reviewed, and confirmed as valid. The research team made notes of such discussions at the time for future reference.

Industry Workshops

The ontology was mobilised in industry workshops to populate nine risk scenarios with relevant treatments. The workshops affirmed the validity of the ontology and the overall approach of the research; both *general* and *practical understandings* of the conceptual ideas being reviewed and discussed by practitioners at the workshops. It should be noted that no contracts or specialised procedures were required to set up the workshops: individuals joined through professional interest and commitment to improving construction health and safety. Resulting from the workshops, a dataset of 9 risk scenarios and 162 treatments were identified to eliminate, reduce, inform, or control (ERIC) the risks covering four different stages of the project lifecycle: preliminary design, detail design, pre-construction, and during construction. The industry workshops maintained and consolidated the relationship with project practitioners.

Prototype Innovation

The dataset of 9 risk scenarios and 162 mitigations provided the basis for the prototype innovation: the dataset being saved as a comma-separated values (CSV) file. At this stage of innovation development, it should be noted that *general understandings, practical understandings* and *rules* regarding the innovation had been discussed several times over with industry experts. *Rules* regarding innovation use had been captured in notes to be taken forward into discussions with software developers. Both positive and negative potential reactions to the innovation by designers and companies (i.e. *teleoaffectivites*) had also been remarked upon several times over in meetings. The research team recognised the importance of addressing these in the work going forward.

S*oftware development*

Following a review of BIM software providers on the market, one specific software vendor was selected and a legal contract set-up between research partners and the vendor so the ontology and dataset could be hosted on a BIM software platform via a specifically designed interface (figure 3). This important step would allow a sharing of the innovation with industry, facilitating further population of the library with data by designers working on multiple projects. The contract with the software vendor was vital to this task: an insight here being the need to reserve project funds for software development (if expertise/capability is not within the research team).

The software vendor contract formalized the *general/practical understandings* and *rules* of use of the innovation, previously discussed in workshops, meetings, etc. Therefore, the "sayings" around innovation use were formalized in written form: specific "rules" that were to be codified into interface functionality of the software. For example, the preference to present project designers with a series of optional treatments for different risk scenarios rather than definitive solutions was codified into interface use (see figure 3). Both *general* and *practical understandings* and *rules* of use of the innovation were later to be made explicit in a printable User-Guide for designers. *Teleoaffectivities* (emotive reactions to the innovation) could only partially be addressed during this stage of work as the research team and software developers attempted to predict possible positive and negative reactions when the innovation would be in use. Further activities needed to be done to address such issues.

Innovation Piloting

Having developed the prototype, it was necessary to pilot it to validate work completed and begin the process of collecting more risks/treatments. Piloting began in Summer 2020 with 4 industry partners and 6 projects. A dedicated support service was setup to assist pilot projects with any questions they had about using the innovation – this service assisting with *understandings* and *rules of use* questions. Whilst each pilot was uniquely different, they all shared a common commitment to identify risks and improve health and safety. It was through piloting that opinion of the innovation was collected, with positive and negative reactions being captured via informal feedback and a more formal survey and interviews. Piloting was therefore very important: changes and amendments to the innovation could be usefully actioned prior to a much larger rollout to industry. By the end of the piloting phase (June 2021), a CSV file containing 401 treatment prompts for 31 risk scenarios related to 11 different risk categories had been added to the BIM risk library. A number of legal artefacts were associated with the piloting work (figure 2). These are discussed in the following section.

Innovation Evaluation

Following piloting and collection of data over a 5 month period, an evaluation process was initiated. A questionnaire survey and interviews with users provided opinions about the digital innovation. The interviews allowed more detailed opinions of the innovation from industry users of the innovation to be captured. Table 2 gives demographic information regarding the survey participants and interviewees.

[Table 2]

The survey revealed that 85% of experts agreed or strongly agreed that the innovation could positively impact design decisions and support selection of appropriate treatments to mitigate health and safety risks. Although 13 is not a large number of survey respondents, the positive comments of construction experts validated the innovation. Furthermore, such a sample number aligns with the guidance of Hallowell and Gambatese (2010), who note the value of small sampling numbers, where a minimum of eight experts is recommended to validate a research proposition. Furthermore, interviewees perceived that adding safety information to a BIM model, and pinpointing risks added value to their safety management processes. Another benefit noted was the structured approach to inputting risk data and the opportunity for collaborative work which the innovation enabled. As part of the evaluation, *understandings*, practicalities of the innovation, *rules* of use and *teleoaffectivities* were all queried through questionnaire survey and interview questions. For further information regarding the innovation survey, see Osorio-Sandoval et al. 2021).

Publicity

The innovation was presented at several national and international events (e.g. Digital Construction Week 2019; BIM for Water event 2019) and subsequently, won two prizes (buildingSMART 2020; Construction Computing Award 2021): these prizes confirming the value of the innovation to industry. Publicity is a vital aspect for any successful innovation, providing opportunity to communicate positive opinions and teleoaffectivity emotions about an innovation to a wider audience.

As noted on figure 2, several legal artefacts emerged as innovation work progressed. Examination of the Collaborative agreements and Data Management Workflow provide evidence regarding how an enactment of a distinct "schema" for innovation delivery became tangible in written form and procedural guidelines.

Collaborative Agreements

Collaborative agreements between industry partners, the HSE and the University detailed specific information and instructions concerning use of the innovation and creation of the BIM Risk Library. These were approved by each party`s legal teams and signed by organisational senior executives. The agreements covered issues such as data protection and anonymisation of data shared with the library. Provision of free software pilot licences to cover the pilot period and specific terms/conditions regarding long term use of data were also detailed. Support to be provided to industry partners, including training and instruction to assist users, and plug-in development to facilitate innovation use with different software packages were also specified in the agreements. A Data Workflow (figure 4) visualizing the data collection process for the BIM risk library was included in the agreements. With the agreements we see a shift from innovation "sayings" to written formalisations of understandings and rules of use, prior to actual "doings" taking place.

As noted, the agreements formalise and make explicit the shared thinking around the innovation (i.e. general/practical understandings of it; rules concerning its` use) already established amongst stakeholders; an absence of shared thinking being identified as potentially detrimental to collaboration if not established (Aarseth et al. 2012). For innovation developers, obtaining formal agreement to use an innovation is crucially important, so the language used to compose the collaborative agreement needs to be worded correctly. The collaborative agreements meet the points noted by Lokuge et al. (2019) as being important regarding organizational readiness for digital innovation: namely, resource readiness, IT readiness, cognitive readiness, partnership readiness, innovation valance, cultural readiness and strategic readiness.

Additionally, the collaborative agreements brought order to the innovation process so that all parties know their roles and responsibilities going forward, facilitating the transformation of the digital innovation from a prototype to technology in use. The underlying parameters form part of an "enacted schema" for innovation delivery (see Discussion), facilitating a collective goal and creating a team ethos and general understanding of objectives (c.f. Uhl-Bien et al. 2007).

Data Management Workflow

Intrinsic to innovation development was the Data Workflow for retrieval, review, anonymization and uploading of data to the BIM risk library. This workflow (figure 4) was integrated into the Collaborative agreements and embodied in processual terms the *rules* and preferences of practitioners regarding innovation use on their projects. For example, the workflow details how risk scenarios and treatments inputted by pilot projects were to be retrieved periodically from the cloud by the research team to be anonymized by removal of sensitive or project-specific information. The overall workflow shows how data was to be collected in a non-intrusive way: this being an effective and important provision of practitioners using the innovation. The workflow was a necessary and informative device to re-assure practitioners how the innovation would practically function, and how data drawn from projects would input into the growing BIM risk library. It complimented and clarified information given in the Collaborative agreements: clear communication on how an innovation will function in the project management context being vital.

[Figure 4]

The workflow also enacting the preferences of industry by defining the operation of the innovation in a project management context: data security; non-intrusive interactions with practitioners; a finite timespan of work activity; an easy to understand plan of action all being clarified. These preferred preferences of innovation users can be understood as being part of the enacted schema for innovation delivery (Figure 6).

Discussion

The review of the BIM Risk library work activities, together with the collaborative agreements and data workflow evidences the presence of Schatzki`s 'organisation of practice' concepts (general/practical understandings; rules; teleoaffectivities – emotive behaviours) that together characterise a distinct practice. The evidence indicates how "sayings" regarding innovation evolve into "doings" via formalised agreements and contracts between parties. Such a transformation is necessary for companies operating in competitive and data sensitive environments. Therefore, whilst the digital innovation journey has been recognised as an "ongoing social accomplishment" pivoting around "negotiated interactions between the main parties" (Bresnen, 2009, p.931), a social practice analysis brings greater clarity to the processes occurring in terms of human behavioural aspects underpinning an innovation. The findings enable further reflections on the existing literature in terms of theoretical and practical contributions.

Theoretical Contribution

The social practice analysis of interactions and artefacts associated with the BIM risk library innovation align with the framework of innovation diffusion of Steiber and Alänge (2015): the five step process (desirability; feasibility; first trial; implementing; sustaining) being evidenced on the BIM risk library in terms of the work activities followed. The social practice analysis adds a layer of detail to this framework in terms of how understandings emerge, rules are established, formal agreements are made and emotive behaviours manifest. With regards to Rogers (1995) six innovation-characteristics that matter for its` diffusion in a social system (i.e. relative advantage for the adopter; compatibility with existing system; complexity/difficulty to learn; testability; potential re-inventions; observed effects), the social practice analysis provided evidence of how each of these are linked to shared understandings, rules and emotive behaviours. A key insight is the importance of relational conditions underpinning innovation use and good working relationships between partners. That mutual dependencies can result in friction, satisfaction or other emotive behaviours (teleoaffectivities) is a reality when using an innovation. The various work activities occurring prior to innovation launch established positive relational conditions (formalised via the collaborative agreements). The empirical evidence suggests that digital transformation is not the simple application of a new technology into a project context, but an all-round transformation of project processes that connect with management, business and organization methods. The paper illustrated how activities leading to innovation development together with the collaborative agreements and data workflow provided a solid foundation for effective innovation delivery.

The interplay between the dynamic process of innovation use and more routinized processes of project management work (Bygballe et al., 2016) has been noted as an important one. The paper illustrates how this dynamic can be played out: the BIM risk library Data Workflow (figure 4) linking to issues of importance for practitioners under pressure to deliver work to time and budget whilst minimising disruption to project processes. Innovation developers and practitioners need to enter into trustful relationships for innovations to be given a chance for success; legal artefacts like collaborative agreements enable innovations to be tested, developed and deployed in transparent ways. The insights from the BIM risk library enable the practice of innovation delivery to be clarified (figure 5) in terms of how "sayings" transform into "doings". As a result, the construction context for innovation may be understood as a distinct "field of practices" (Schatzki, 1996, 2001) with its` own distinctive schema of "preferences and prescriptions" (Knorr Cetina, 2001) of developers and practitioners, as highlighted in figure 6. Reference to such a schema is useful for both technology developers and innovation developers addressing practicality issues.

[Figure 5]

Practical Contribution

Digital innovations demand changes to working practices (c.f. Cicmil and Marshall, 2005), with new practices emerging as people coordinate in new ways (Cicmil et al. 2006; Sage et al. 2012). A social practice analysis clarifies how this happens in actuality (in terms of understandings, rules and emotive behaviours). Such a study extends understanding of the decision-making processes managers use in the adoption of new technologies and strategies used to deal with uncertainty (Mitropoulos and Tatum, 1999). On the BIM Risk library, industry partners signed collaborative agreements following extended periods of discussion with research partners, establishing their understandings and agreed parameters of innovation use. Deriving from the BIM risk library, figure 5 illustrates how such discussions formalise into agreements prior to innovation use. As indicated in figure 5, the practice of innovation delivery and its` associated sayings, doings and formalisations may be visualised to have a relationship within which the preferences of stakeholders are emergent, formalised and enacted upon.

If we follow Knorr Certina`s (2001) definition of practices as "recurrent processes governed by specifiable schemata of preferences and prescriptions", we can begin to identify an underlying schema for innovation delivery in construction. Analysis of the BIM Risk Library assists in such a process and adds a level of social understanding lacking in models such as the technology-acceptance model (TAM) that fail to recognise user acceptance over time (Liu et al. 2018). Figure 6 draws together insights from the empirical evidence to present an enacted schema for innovation delivery in construction. It is contended the schema should be reflected and enacted upon in order to make an innovation successful in a construction context. Additionally, the schema addresses the three tenets of Havenid et al. (2019) in a recent collection of works on innovation in construction; these tenets being to shed light on the organisational processes within contexts of innovation in construction; to apply novel theoretical perspectives to empirical phenomena, and to recognise the temporal and spatial distribution of innovation as processual activities.

[Figure 6]

The figure 6 schema notes the prescriptions and preferences of developers and practitioners for effective innovation delivery. Developer prescriptions include clear definitions of the purpose and benefits of an innovation; clarity over roles/responsibilities of parties; clarity on how the innovation will work/function. Preferences note aspects which would support successful innovation deployment, including the social practice concepts of Schatzki and the need to minimize disruptions to project work processes. A developer preference would be the importance of reducing negative emotive reactions whilst promoting positive reactions if possible. The collaborative agreements, data workflow (embodying general/practical understandings, rules and purpose of the innovation), and user guide emerged as the project evolved at a moment in time that was required for progression of the innovation. These artefacts of innovation embody the prescriptions and preferences of developers and practitioners. These are shown in figure 6 as emerging from the processes. The various meetings, communications and work interactions preceding their creation were important in preparing industry partners for the innovation itself and laying the groundwork for its` uptake.

Conclusions

The paper advances understanding of successful digital innovation delivery in construction project management through a social practice analysis of various activities and outputs associated with one innovative technology (the BIM risk library): i.e. discussions; legal agreements; innovation workflow; software artefact; user guide). A limitation of the paper is that the insights are drawn from one single study of innovation delivery. Whilst single case studies can be criticized from a data limitation point-of-view, it should be noted that 4 different companies used the innovation on 6 separate projects over several months. Therefore, the data upon which the study is based is not insubstantial. Additionally, as the innovation has garnered attention and won awards, it is contended that the insights of the paper are useful and informative for industry innovators and the academic community. Additionally, the paper provided tangible insights into how an innovation can emerge from context-specific interactions (e.g. industry workshops; software vendor negotiations; piloting work) where general and practical understandings of an innovation, rules regarding its' use and teleoaffectivities (emotive behaviours) are part of the discourse. Employment of Schatzki`s 'organisation of practice' concepts to examine the interactions occurring and the resultant artefacts shared between collaborators highlight the importance of understandings, rules and emotive behaviours in the innovation journey. Whilst the evolutionary nature of innovation development was described, a distinct 'field of practice' for innovation delivery came into focus, with a 'schema of generalisable preferences' emerging from the social practice analysis (figure 6). Artefacts such as legal agreements, software product and innovation workflow evidenced how the innovation discourse shifts from verbal "sayings" to formulised agreements and contracts that embody the preferences and prescriptions of practitioners: the practical realities of innovation use being translated into a tangible schema prior to their "doing" in construction project contexts. The findings complement existing frameworks for understanding innovation delivery in project management contexts and provide an extension to the body of knowledge on factors contributing to innovation delivery in construction.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available in a repository or online in accordance with funder data retention policies (https://www.discoveringsafety.com/).

Acknowledgements

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Disclaimer

The author reports there are no competing interests to declare.

Ethics Statement

The research obtained ethics approval from the University of Manchester Ethics Committee. Subsequently, informed consent was received from the research subjects.

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Figure captions

Fig 1. Framework for diffusion of innovations

Fig.2. BIM risk library screenshot

Fig.3. Flowchart of work activities

Fig.4. Data management workflow

Fig.5. Practice of innovation delivery

Fig.6. Schema for innovation delivery

Practical Understandings	Knowing how to execute desired actions through basic doings and sayings.
Rules	Formulated directives, admonishments and edicts; rules can be defined as “methodically applied generalizable procedures of action”.
Teleoaffectivities	Acceptable and enjoined emotions, moods and actions associated with certain practices.
General Understandings	Understandings or senses of general matters pertinent to goings-on in practices.

Table 1: ‘Organization of practice’ concepts (Schatzki, 1996)

Expert ID	Area of work	Experience in the construction industry (Years)
EXP-01	Design	45
EXP-02	Other (specify) *All stages*	41
EXP-03	Other (specify) *All stages*	40
EXP-04	Design	5
EXP-05	Other (specify) *All stages*	44
EXP-06	Strategic planning	15
EXP-07	Construction	33
EXP-08	Design	40
EXP-09	Construction	33
EXP-10	Construction	49
EXP-11	Design	33
EXP-12	Other (specify) *CDM Principal Designer*	35
EXP-13	Design	28

Table 2: demographic information of survey/interviewee experts

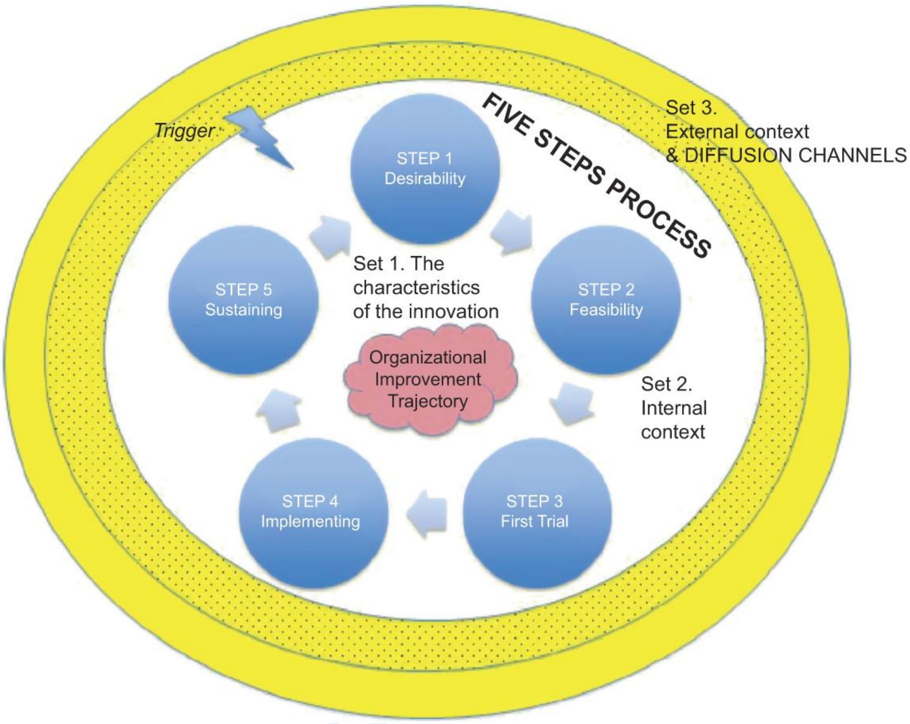

Figure 1: Framework for diffusion of innovations (Steiber and Alänge, 2015)

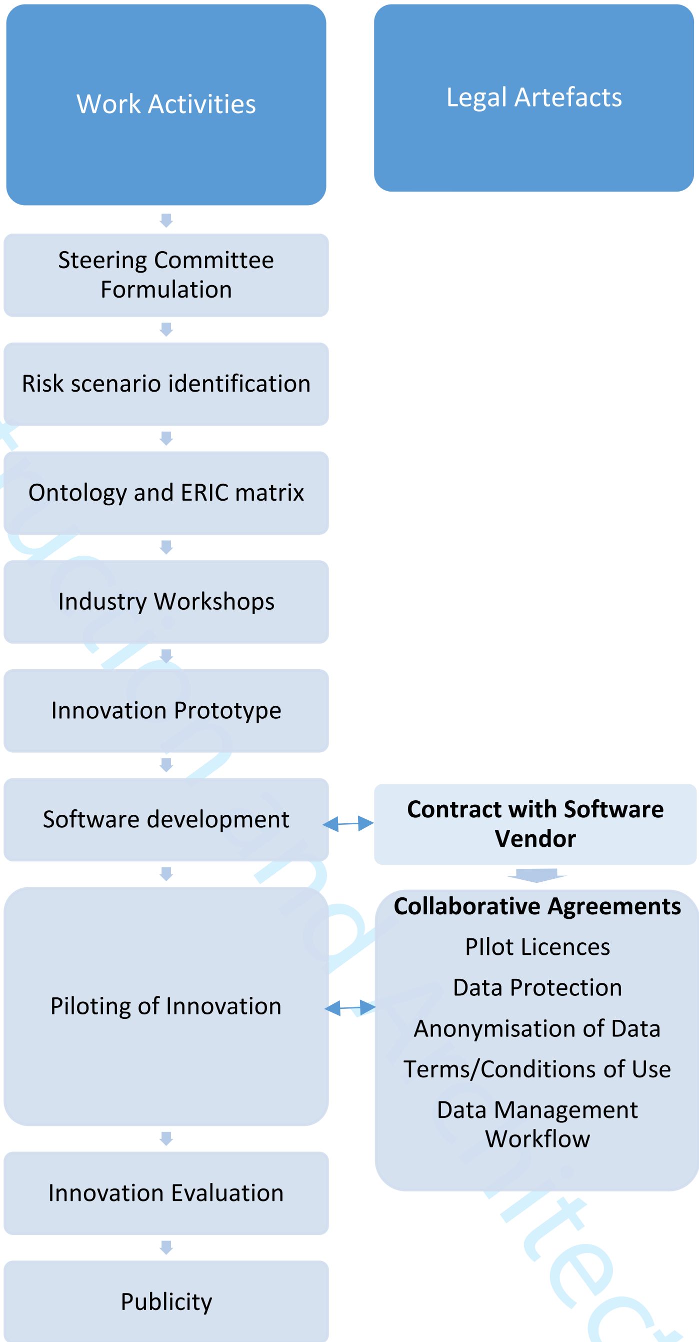

Figure 2: Flowchart of work activities

Figure 3: BIM risk library screenshot (from Project Safety Journal, Winter 2022, p.14)

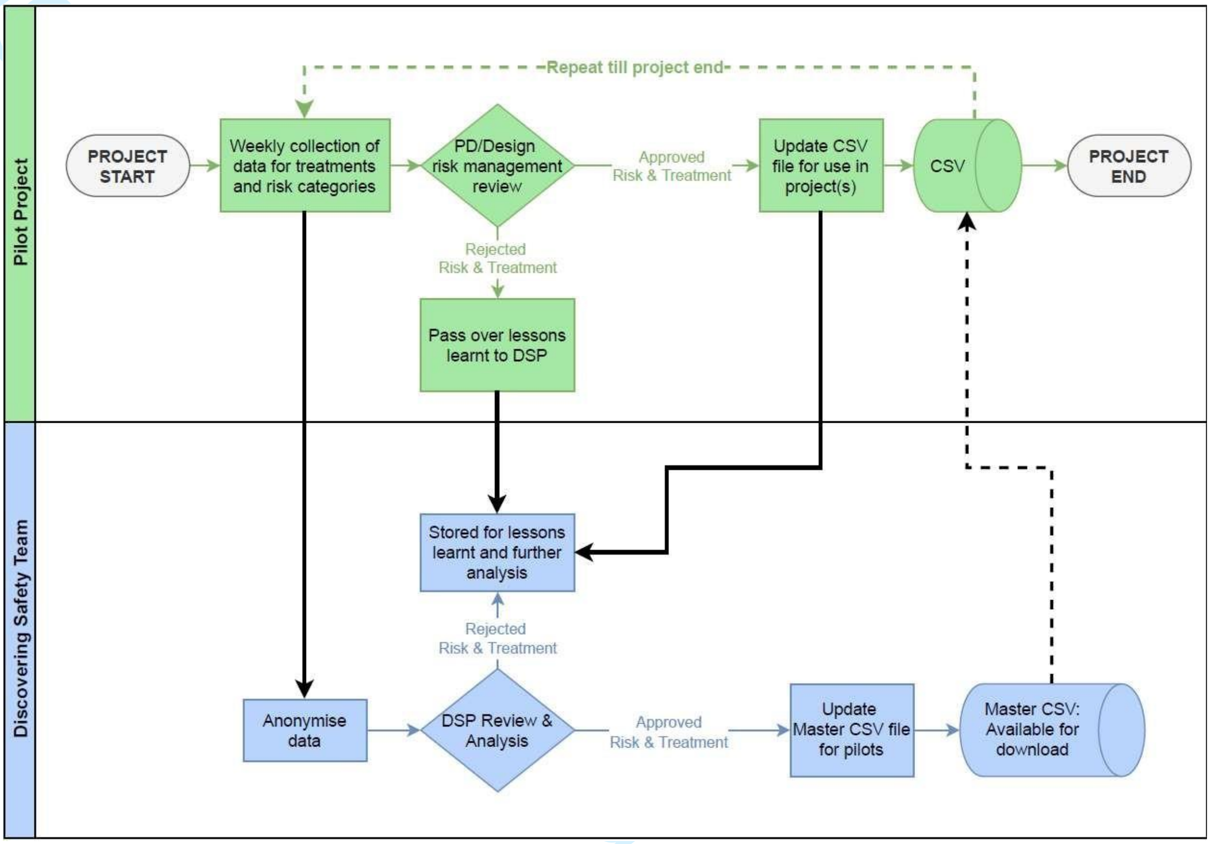

Figure 4: Data management workflow (from Osorio-Sandoval et al. 2021, p.9)

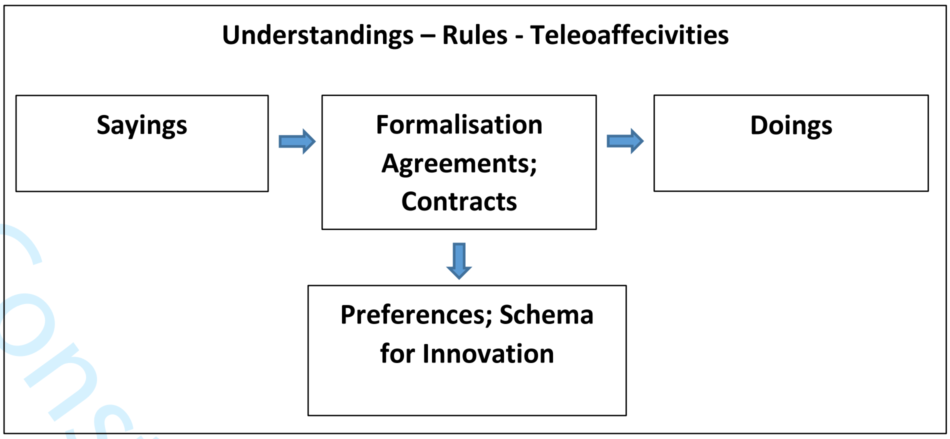

Figure 5: Practice of innovation delivery - sayings, formalisation, doings

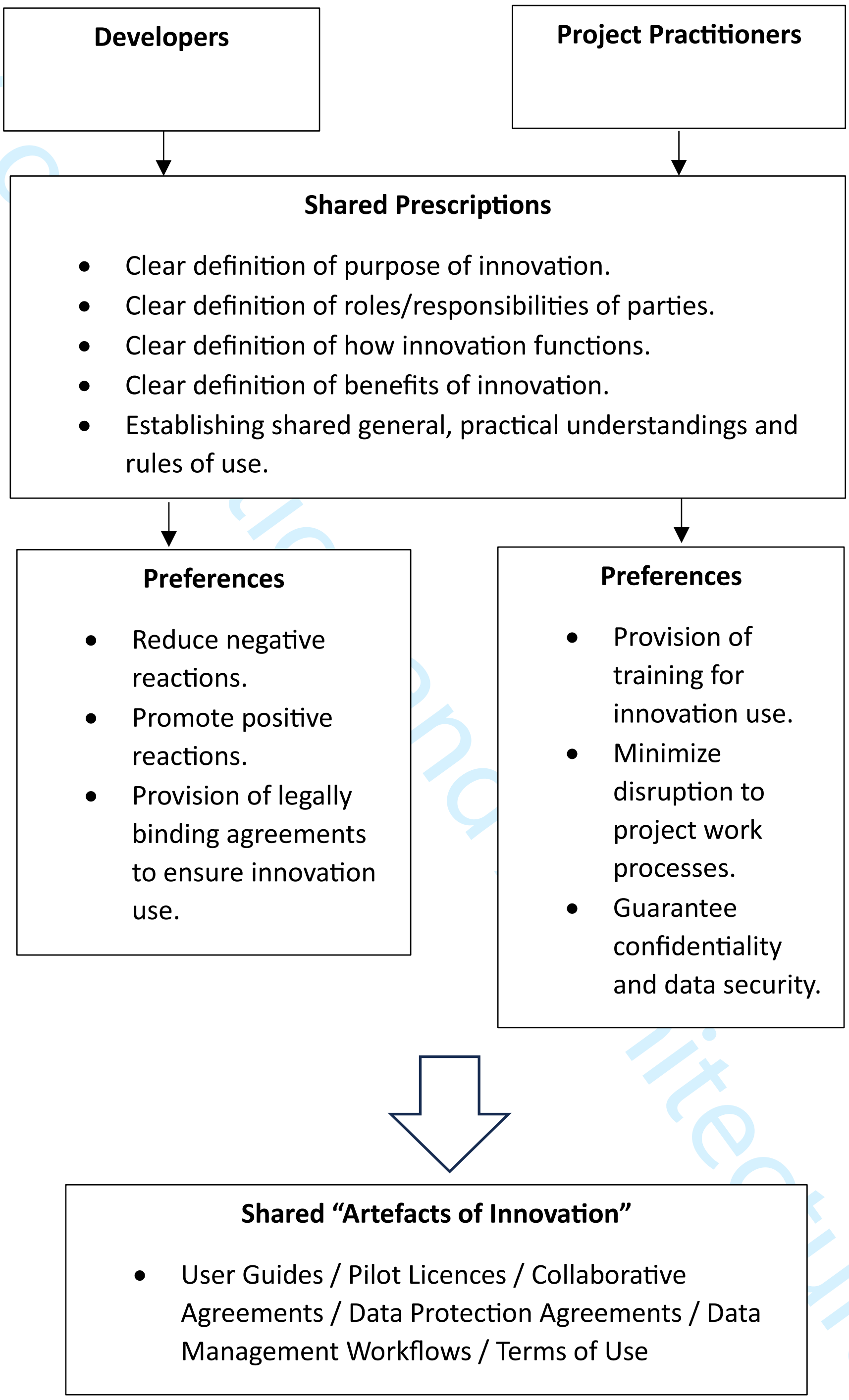

Figure 6: Schema for innovation delivery

Reviewer Comments & Responses

The author/s thank the Reviewers for all their comments and detail below the responses. Reference to manuscript lines of text refers to the Tracked Changes version of the paper.

Reviewer 1 Comment	Response
1) Given the tile is "digital innovation delivery", it would be interesting to see the analysis of innovative technologies used in the project production and construction such as robotics and other digital tools.	The paper analysis and contribution stems from one digital technology: the BIM Risk Library. Whilst further studies on other digital technologies is merited and valuable (e.g. robotics), it is beyond the scope of the paper.
2) Majority of the references seem outdated. This impedes some statements from generating a firm conclusion and might leave out some state-of-the-art studies to this study.	A further literature review identified several more recent papers regarding innovation in construction. These have been integrated into the literature review section (lines 135 - 142). No specific more recent papers were identified that that adopted a social practice theoretical and conceptual analysis of innovation as this paper does.

Reviewer 2 Comment	Response
FIgures 4 and 5 should be adopted on the context of this research. The main innovation made (BIM Risk Library) and its elements should be linked into these FIgures.	The accompanying text in the paper for Figures 4 and 5 and the Figure labels have been amended to clarify the link between the BIM Risk Library and the figures themselves.
Limitations should go to the Conclusion section.	This comment has been addressed. The Limitations text being moved to lines 665 - 671.
It is recommended to not incorporate citations and references in the Conclusion section.	This comment has been addressed.
The methodology should be enhanced. Its methodological standpoint and foundation should be theorized first and the, the research process and steps can be built upon.	The methodology section has been revised and enhanced. The theorization and practical aspects of the methodology are now clearly demarcated.
The presentation and visualization of the results should be significantly improved.	Thankyou for the comment. The original schema of innovation delivery (Table 3) has now been replaced by a new figure 6 and further text in the paper to enhance the presentation and visualization of the results.

Reviewer 3 Comment	Response

In its present form, the abstract appears to lack specificity and clarity regarding the study's purpose, adopted methodology, results and key findings, and the expression of the originality of the work. The abstract should provide a concise yet comprehensive overview, clearly outlining the aim of the study, describing the methodological approach used, highlighting key findings, and emphasising the original contributions of this research.	The Abstract has been reviewed and revised in light of the comments.
The originality of this study should be more specifically presented in the abstract and introduction sections.	The text has been edited and new text added to these sections (Abstract & lines 109 – 113).
The literature lacks critical reviews of digital innovation delivery and the BIM Risk Library. The current section only discusses the practice of innovation delivery and social practice theory. But the link between digital innovation delivery, i.e., the BIM risk library, is not sufficiently presented.	The work processes of the BIM Risk Library and the analysis of those processes using social practice theory is the main focus of the paper and is not presented in the Literature Review section. The Literature Review sections have been reviewed and improved in places (see comment above). A further literature review was done in light of this comment, but no further relevant papers regarding application of social practice theory were identified to integrate into the text. If the reviewer believes there is a specific omission regarding specific reference/s, the author/s would be pleased to integrate them into the text as necessary.
Lines 137: "analysis of exemplar "successful" innovations can provide the empirical data" discussing some examples here would be beneficial to prove your argument.	The argument is from Söderlund, and is not the author/s own.
In the literature review section, the paper initiates a discussion on practice theory starting from line 147 onwards, wherein the authors delve into examples illustrating epistemological and ontological uncertainties. However, the current exposition, particularly in lines 150 and 155, lacks precision, leaving questions about the link between the examples and their contribution in the broader argument. To enhance clarity and conciseness, it is recommended to refine this part, ensuring they are both comprehensive and directly relevant to the overarching points regarding epistemological and ontological uncertainties.	The criticism is that the section of text lacks precision in noting the deficiencies in practice theory studies. These deficiencies are as reported by published work in the field. For example, O`Keeffe et al. note it is the "doing" and "performance" of practice that should be the basis of practice theory analysis, whilst Marshall notes that practice theorists often fail to provide empirically sound demonstrations of theoretical propositions in action. However, further text has been added to the section to clarify the argument being made (lines 188 – 190).

The overall presentation of the methodology is okay. However, it needs to be more organised and concise yet comprehensive.	The methodology section has been reviewed and revised in light of the comment.
It is suggested to include aspects that were raised via questionnaire survey and interviews in detail. Does the survey include only 13 participants? If yes, what is the justification for generalising the finding in Line 439 (the survey revealed that 85% of experts agreed or strongly agreed…).	Views of the innovation from the questionnaire survey and interviews have been integrated into the paper (lines 474; 480- 484). An additional reference to the survey has been added (line 485 486) for readers wishing to follow up this issue. Regarding the survey, and the 13 valid responses, further text has been added to the paper to support the validity of presenting views from the 13 responses (lines 476 - 480). A supporting reference for the use of such a sampling number is also provided (line 478).
Why were two different data collection methods employed (with the same set of participants)? The data collection procedure should be more comprehensive.	The data collection procedure was comprehensive in that all pilot projects using the innovation together with many expert practitioners were questioned and surveyed for their opinion. Further text has been added (lines 469; 476 – 480; 485 -486) to explain why a survey instrument and interviews were used.
The discussion should not dominate the new literature; however, the key finding should be supported with relevant evidence. In some cases, the discussion could be further enhanced by providing some practical examples that explain the results of this study.	The discussion has been revised in order to improve communication of the key findings of the paper. In addition to changes in the text, a new figure 6 has been added to the Discussion to achieve this.
Please check for typos and minor syntax errors.	The paper has been checked and corrected where necessary.

Advancing social practice understandings of digital innovation delivery in construction project management

Abstract

Purpose

The paper ~~purpose is to~~ applies social practice theory to clarify the process of innovation design and delivery from ~~design and delivery in construction project management contexts through examination of~~ one successful digital innovation: the BIM risk library. The paper clarifies the practices surrounding construction innovation and provides a schema useful for practitioners and technology designers ~~builds upon scholarship in the field, contributing to the body of knowledge by extending existing frameworks of innovation diffusion~~ through a social practice analysis.

Design/methodology/approach

The paper applies ~~Information is drawn from a research project that delivered a new digital innovation for industry to improve construction health and safety. Application of~~ Schatzki`s 'organisation of practice' concepts to a~~the~~ construction project innovation to clarify how the ~~process provides insights into the~~ practice of innovation ~~delivery for construction project management~~revolves around understandings, rules and teleoaffectivities (emotive behaviours). Sources for the study include notes from meetings, workshops with experts and the shared artefacts of innovation.

Findings

~~Findings include~~ The practice of innovation design and delivery are clarified through a social practice analysis: a distinct "field of practice" and ~~for innovation delivery together with~~ a

“schema” of generalizable prescriptions and preferences for innovation delivery ~~to be followed by innovators~~being presented.

Originality

The social practice analysis of one~~a~~ successful construction ~~project~~ innovation is an original contribution to the body of knowledge, ~~. The paper~~ add~~ings~~ a level of detail regarding innovation design and delivery often missing from ~~previous~~ reported research.

Practical implications

The paper informs the practice and process of innovation design and delivery; ~~for technology developers and researchers in the field. T~~the insights clarify~~y~~ how collective understandings ~~of an innovation~~ and rules of use evolve over time, becoming formalized into contracts, agreements and workplans. Practically, ~~The~~ processes whereby innovation ‘sayings’ evolve into innovation ‘doings’ are clarified:~~;~~ a schema ~~for innovation delivery~~ detailing ~~ing~~ prescriptions and preferences of practitioners and ~~innovation~~ developers being presented ~~being presented~~.

Keywords: innovation studies; BIM; building information modelling; digitalisation; projects-as-practice; social practices; health and safety; data engineering.

Introduction

Managing an innovation is as important as the innovation development process itself (Bamel et al. 2023); construction project management innovations being interventions into existing complex working practices (Liu et al. 2018). As such, aligning an innovation to those practices to minimise disruption and continue business-as-usual processes is important. Additionally, the process of innovation adoption whereby an innovation becomes part of everyday project-based working practice remains unclear: innovation adoption being a complex business, with little to guide practitioners through the messy and contingent process of adoption and diffusion (Harty, 2005). Therefore, understanding how innovations are delivered is ~~as~~ important for improving innovation practice itself (Havenid et al. 2019). Whilst Winch (1998) notes that more case studies of trajectories of innovation are required in order to identify who generates new ideas and how they are managed into “good currency”, the process of innovation design, prototyping, testing and deployment requires a theoretical and conceptual unpacking using empirical evidence. This paper makes a contribution by examining how one successful digital innovation was developed and deployed with several project-based organizations to become part of their everyday working practices. The innovation (the BIM Risk Library) was recipient of several industry awards (buildingSMART, 2020; Construction Computing Award, 2021) and therefore provides valid data regarding a "successful innovation". Amongst the key questions posed by the paper are: what contributes to successful innovation deployment in ~~a~~construction project management ~~context~~? What are the drivers and inhibitors of successful innovation delivery? How can the innovation delivery process be conceptualised and ~~better~~ understood?

The paper adopts a projects-as-practice (Blomquist et al. 2010) approach and uses social practice theory (Schatzki, 2001) to review the process of innovation delivery. The case for adopting a projects-as-practice approach for understanding what occurs on projects has been made for some time (c.f. Koch et al. 2019; Blomquist et al., 2010; Clegg et al. 2018). In outlining a projects-as-practice approach to conducting research in project management, Blomquist et al. (2010) note that project management is an immature field of research, where many of the normative and traditional contributions are insubstantial when it comes to understanding what is really occurring in projects (see Winter et al. 2006). Clegg et al. (2018) argue that practice-based research provides a methodological lens to explore the reality of project management work; the authors noting that practice-based perspectives are under-represented in project portfolio management (PPM) research, whilst presenting an agenda for further practice-based research, including its discursivity, representation, dynamic capabilities, leadership and materiality. This paper follows this tradition by employing a "social practice" theoretical perspective to ~~previous~~ established frameworks for innovation diffusion; the framework of Steiber and Alänge (2015) being ~~providing~~ a foundation upon which a social practice analysis of processes and interactions may be overlaid.

The paper adopts a granular analysis of the ~~discussions and~~ interactions between ~~the~~ innovation stakeholders to identify the concepts characterizing a 'practice of innovation delivery' that pivot around rules, understandings and teleoaffectivities (emotive behaviours). The analysis of the work around one successful digital innovation (the BIM Risk Library) –leads to identification of specifiable enacted schemas (i.e. practitioner preferences and generalizable procedures) to be addressed by innovation developers. As a result, ~~it is argued that~~ the practice of innovation delivery in construction contexts is noted to be ~~is~~ distinctive and governed by specifiable preferences and prescriptions (Knorr Cetina, 2001): understanding construction working practices and aligning an innovation to those practices being critical for successful innovation ~~development~~design and deployment. The originality of the work arises from the analysis of each step of the innovation design and delivery process and its' associated artefacts using Schatzki's practice theory concepts. The contributions which result, around sayings, formalisations, doings and a schema for innovation delivery add to the body of knowledge concerning construction project innovation.

The paper is organised as follows. A literature review scopes out understandings of the practice of innovation delivery in construction, identifying gaps in knowledge and issues requiring clarifications. The projects-as-practice literature and social practice theory of Theodore Schatzki are then presented to provide theoretical orientation and foundation ~~for the study~~. A methodology section describing the research approach adopted is followed by presentation of the innovation: the BIM risk library: a collaboration between ~~the~~ University of Manchester (UK), the UK regulator for workplace health and safety ~~in the UK~~ (the Health and Safety Executive – HSE), several construction companies and a building information modelling (BIM) software provider. The ~~A~~ high-level review of ~~work concerning~~ innovation development work is complimented by deeper analysis of the collaborative agreements between partner organizations and ~~the~~ data management workflow employed for innovation data harvesting and development. ~~that emerged following discussions between research partner organisations.~~ Collectively, this evidence distils the ‘field of practice’ (Schatzki, 1996) of innovation delivery in construction with an “enacted schema” for innovation delivery coming into focus from the analysis. A following discussion notes how the social practice findings align and enhance ~~build upon~~ the framework of innovation diffusion of Steiber and Alänge (2015): innovation evolution being understood in social practice terms, with a schema~~”~~ for innovation delivery and relations between “sayings”, “formalisations” and “doings” being presented. A closing conclusion draws the insights of the paper together.

Understanding the Practice of Innovation Delivery

Recent published work regarding innovation in the construction industry has addressed a variety of subjects, including the effect of supply chain innovation on competitive advantage (Afraz et al. 2021), open innovation and the enhancement of productivity (Greco et al. 2021), innovation ecosystems and collaboration in infrastructure projects (Vosman et al. 2023) and boundary-spanning for managing digital innovation in the AEC sector (Azzouz and Papadonikolaki, 2020). Whilst these contributions have added to the body of knowledge concerning innovations in construction, there remains a need to understand the practice of innovation delivery. In this respect, whilst ~~Whilst~~ diffusion of innovations across firms has been recognised as a non-linear process (Shibeika and Harty, 2015), ~~academic~~ research has also examined how companies organise for digitalization (Morgan, 2019). However, understandings of the practice of innovation delivery are opaque and ambiguous: understanding the trajectory of a digital innovation (Winch, 1998), and how an innovation transforms from research idea to a fully-fledged application being much less understood. It has been noted that the relationship between system developers and potential industry users can be contentious (Liu et al. 2018), with challenges towards industry uptake of innovations being considerable

(Oesterreich and Teuteberg, 2016). Whilst technical, practical and social barriers to innovation uptake are commonly evident (Collinge et al. 2020a), Blindenbach and Van Den Ende (2010) note that project-based firms have more difficulty innovating ~~their own~~ products, services and operations as compared to when they innovate for their clients. As a result, suitable engagement strategies and appropriate working relationships with technology developers need to be established. Blindenbach and Van Den Ende (2010) also note that the effects of specific management practices on project performance are different, particularly the effects of planning, multidisciplinary teams and heavyweight project leaders. The authors note that differences in firm characteristics provide an explanation for the findings; an implication for the innovation management literature being that "best" practices for innovation management are firm dependent. Söderlund (2004) points out that process and real-time case studies and project organization issues are of particular interest, and therefore analysis of exemplar "successful" innovations can provide the empirical data needed for such studies.

Cicmil (2006, p. 36) asserts that project theory would be served by a qualitative approach with a critical interpretive lens that might 'generate alternative understandings of what goes on in project practice and how practitioners participate in and manage complex organizational arrangements.` Consequently, examination of what people do in ~~within the context of~~ project contexts is a valid analytical approach rather than a confirmation of best practice models for project management (cf. Geertz, 1973). This aligns with Blomquist et al. (2010), who argue for a practice perspective (Schatzki, Knorr Cetina, & von Savigny, 2001) that begins with individual actions and asks what overall models and concepts result from those actions.

Practice theory has been used to study interactions in construction project management contexts previously, for example to understand digital integration of built-environment practices (Çıdık et al. 2017) and collaboration in construction (Connaughton and Collinge, 2021), but epistemological and ontological uncertainty remains, particularly regarding the delivery of innovations in construction project management. For example, whilst Bresnen (2009) argues that a 'practice' perspective allows us to focus on what happens in actuality: understanding practices being potentially more informative than industry-wide models of ideal processes, Marshall (2014, p.110) notes that practice theorists often fail to provide empirically sound demonstrations of theoretical propositions in action, thus limiting the usefulness of ideas. For example, the practice theory objective to clarify the emergent and ongoing constitution of social orders and change through situated practices has not been substantially engaged with. Similarly, whilst Blomquist et al. (2010) propose a 'project-as-practice' approach for understanding the complexities of working practices occurring in projects, noting the specific challenges for the researcher, O'Keeffe et al. (2015) comment that it is the 'doing' and 'performance' that should be the basis of analysis in practice theories when stating,

'Practice theory refocuses attention on the social nature of organized activities and how these relations are mediated by the materialities within which they become enmeshed.' (p. 416). This paper directly addresses the comments of Marshall (2014) and O'Keeffe et al. (2015) above by providing an empirical demonstration of practice theory concepts in action, and by highlighting the "doing" and "performance" of innovation practice in a construction context.

Whilst the above~~se~~ reflections highlight the importance of empirical evidence for informing theoretical understanding of practices, in terms of models of innovation, important work has already been conducted in the field. Rogers (1995) notes six innovation-characteristics that matter for its diffusion in a social system; these being: its relative advantage for the adopter, its compatibility with the pre-existing system, its complexity or difficulty to learn, its testability, its potential for re-inventions, and its observed effects. Building on the work of Rogers, Steiber and Alänge (2015) present an analytical framework for diffusion of innovations (figure 1). The framework includes five steps that a firm goes through when searching for, adopting, and implementing~~,~~ either a technical or organizational innovation: the five steps being desirability, feasibility, first trial, implementing, and sustaining. These five steps are in turn dependent on a firm's organizational improvement trajectory, which is cumulative and path-dependent due to increased return on investment on existing innovations, as well as on internal inertia among board members, top managers and employees. The five steps are all subject to three sets of influencing factors: characteristics of the innovation, the internal context, and external context (that include diffusion mechanisms).

[Figure 1]

In figure 1, the five steps are visualized as a circular pattern around an organizational improvement trajectory. The framework of Steiber and Alänge (2015) provides a validated model for the digital innovation delivery process by which activities could be analysed or planned. More recently, Steiber et al. (2021) explored the digitization process for industrial firms, presenting a validated framework based on innovation diffusion theories and case study evidence, with inhibitors and drivers of digital transformation being identified. As Steiber et al. (2021) note, diverse theoretical perspectives and new research methodologies are needed in order to understand the major challenges that block or hinder firms` deployment of digital technologies. These insights reveal how there remains a need to understand the practice of innovation ~~design, development and deployment~~ in clearer terms.

Social Practice Theory

Theodore Schatzki`s social practice theory (1996; 2002) enables a domain to be examined as a ‘field of practices’ with ever evolving ‘nexuses of doings and sayings’ (Schatzki, 1996). Although Schatzki (2001) notes that practice can refer to both individual performed activities and a guiding principle for activities, Knorr Cetina (2001) observes that the majority of scholars agree with the definition of practices as:

'recurrent processes governed by specifiable schemata of preferences and prescriptions' (p.175)

Schatzki`s theory of practice (1996; 2002) is generally considered as one of 5 current approaches to studying practice (other approaches being communities of practice; activity theory; ethnomethodology and discourse analysis: Nicolini, 2012). Nicolini (2012) encourages researchers to draw selectively on concepts from different approaches to illuminate various aspects of practice, proposing a "toolkit approach" for empirical work. Such flexibility makes practice theory a potentially attractive methodological approach, whilst also remaining challenging. As Schatzki (2012) comments,

'The world according to practice theory offers much to investigate. There are practices, arrangements, activities, bundles and constellations. There are questions about which of these exist, when and where, their details, how they work and unfold, how they can be designed or altered, and how to prepare people to enter them.' (p.23)

Schatzki (1996) maintains that practice is a "temporally unfolding and spatially dispersed nexus of doings and sayings, embracing notions of activity and organization" that make up people`s "horizons of intelligibility" (Nicolini, 2012). Caldwell (2012) maintains that Schatzki`s ambition is to ensure practices are ontologically more fundamental than language and discourse: practice actions (the "*doings*") taking priority over practice language (the "*sayings*"). Consequently, Schatzki gravitates toward a concept of agency as "doing", underplaying the role of language and discourse (Schatzki, 2002); in this scheme verbal and non-verbal signs are part of the "doing" of a practice rather than its principal components. Schatzki therefore distances his theory from those of Bourdieu and Giddens by rejecting Bourdieu`s concept of "habitus" and Giddens concept of "practical consciousness" (Caldwell, 2012).

Whilst practice theorists generally maintain the social as a field of embodied, interwoven practices organised around shared practical understandings, the concept of "*field of practice*" or "*site of the social*" (Schatzki 2001) distinguishes Schatzki`s theory from those of others (c.f. O`Keeffe et al., 2015; Nicolini, 2012). This notion can best be described as the *context* within which practices occur: a "fields of practice" analysis being one that: a) develops an account of practices and/or b) treats the field of practice as the place to study the nature and transformation of their subject matter. This ontology comprises an array of orders and arrangements of people, artefacts and entities that constitute the organized activities of that place (Schatzki, 2001): the practices within a context being made explicit to identify the "practice-arrangement bundles" of which those practices are part (O`Keeffe et al. 2015). As Schatzki (2013) states:

'The coalescence of a practice involves some combination of (1) the emergence of common rules (explicit formulations) in the light of which actors proceed, (2) the crystallization of sets of prescribed or acceptable ends, tasks and actions, (3) the development of common practical understandings, and (4) the distillation of common general understandings.' (p.37)

With a social practice approach, examination of the digital innovation experience cannot be understood separately from its` context: that context being a "field of practices" within which the innovation resides. As stated earlier, there is value in clarifying what constitutes a supportive context for delivery of an innovation. Schatzki`s classifies the 'organization of practice' into 4 concepts (Table 1).

[Table 1]

Referring to Table 1, an action belongs to a practice if it expresses one of the understandings, rules or teleoaffective conceptsthat organize that practice, with activities forming a nexus in that they are organised and connect together through such relations as causality and intentional directedness (Schatzki, 2012, p.15). Of the above concepts, teleoaffectivities may be the most difficult to conceptualise. It is best understood by conceding that separate practices possess their own sets of acceptable and enjoined intentions, actions, emotions and moods (Schatzki, 1996, 101). In construction, intentions or goals are often influenced or directed by normative and emotional behaviour (Caldwell, 2012, 290), with certain teleoaffectivities being associated with specific practices. For example, a project team may express surprise and shock at a supplier quote five times above the going rate. Teleoaffectivities are those emotions, moods and actions that become associated with certain practices.

For an innovation, teleoaffectivities (i.e. positive or negative reactions) are potentially significant to the success or failure of the innovation. For example, surprise and joy at being able to perform a task not previously possible would be a positive teleoaffectivity, whereas frustration or confusion about innovation use would be a negative teleoafectivity. Therefore, developers must be aware of teleoaffectivities and build-in processes to ensure possible negative reactions are mitigated. This can be done via engagement activities, workshops and pre-piloting work.

Schatzki (2002) also states that “human agency must be understood as something contained in practices” (i.e. as the performance of doings and sayings that constitute the actions that compose practices" p.240). Similarly to Schatzi, Sewell (1992), a practice theory scholar, understands practices as enacted schemas (i.e. generalizable procedures) that can be transposed from one domain to another, but that also organise and constrain other schemas. This paper takes forward these ideas and Schatzki`s 'organization of practice' concepts to investigate the practice of digital innovation delivery on the BIM Risk Library.

Methodological Approach

Theoretical Positioning

Theoretically, the research may be categorised as "social-science based" and "process-oriented" rather than "engineering-focused" ~~based~~ research (see Blomquist et al, 2020, p.6). As a 'theories-in-use' contribution (Söderlund, 2004), the focus on project processes enables a theory and its` associated concepts to be applied and examined objectively. In this case, the paper applies social practice theory and the concepts of Schatzki (Table 1) to understand the process of innovation delivery, such an analysis taking into account the complexities of human life (c.f. Cicmil and Hodgson, 2006, p.10). Such an examination of social processes at work (i.e. how understandings, emotions and rules emerge, evolve and become formalized) addresses the need for more fine-grained studies of the microactivities occurring, as noted by Blomquist et al. (2010, p.7). Methodologically, this paper follows the lead of O'Keeffe et al. (2015) in focusing upon the "doing" or "performance" of innovation, and the processes leading up to such "doings" in a construction project management context.

Practical Details

Practically, in terms of methodological steps, ~~F~~figure 2 presents the overall flowchart of work from the BIM Risk Library project. A series of 'legal artefacts' associated with phases of work activity are also highlighted: these legal artefacts being critical to the mobilisation of the innovation. Methodologically, to conduct a social practice analysis of the work occurring, each separate work activity was examined by the researcher using the ‘organization of practices’ concepts of Schatzki (1996) (Table 1). This meant identification of how rules, understandings (both practical and general) and teleoaffectivities (emotive behaviours) manifested through spoken dialogue, shared artefacts and plans of action to be taken forward. Sources of data included notes from meetings, ~~and~~ the workshops with industry practitioners ~~taken by the researcher~~ that captured thoughts and reactions to the innovation by industry experts, and the shared artefacts that played prominent roles in the innovation design and delivery journey (i.e. collaborative agreements; data management workflow; user guide; software tool). ~~.~~The multiple meetings between research team and industry partners were recorded on a Trello board, providing a further source of data. ~~, as did the artefacts that emerged as part of the innovation journey (collaborative agreements; data management workflow; user guide; software tool).~~ As will be noted, the shared artefacts, such as the collaborative agreements and data ~~management~~ workflow formalised how the innovation would operate and function. A post-pilot survey of practitioners and interviews with individuals provided a further source of data for analysis. The researcher examined the data chronologically, in logical order, as noted on the figure 2 flowchart of work activities. ~~The paper also presents the research findings in the same way.~~

Regarding the meetings and workshops with industry, ~~attended by the researcher and captured via notes,~~ it should be noted that discussions (i.e. spoken words) between stakeholders revolved around the functioning of the innovation, how it should/could be used and how it would potentially impact (positively or negatively) ~~construction~~ project work practices. Whilst acknowledging that such conversations and ‘messy talk’ ~~of professionals~~ are intrinsically a part of collaboration using BIM (Dossick and Neff, 2011), the focus of analysis was the 'organization of practice' concepts of Schatzki (Table 1) and how and when they manifested themselves. As noted, this manifestation would be through spoken dialogue, shared artefacts and plans of action to be taken forward. Such a microanalysis of processes takes into account the complexities of human life for a practice-oriented study (c.f. Cicmil and Hodgson, 2006, p.10): the deeper examination of interactions occurring also addressing the need for fine-grained studies of the work occurring (Blomquist et al. 2010, p.7). As noted in the following sections, the social practice analysis facilitateds clarifications of how 'sayings' transform into 'doings' of innovation delivery and use; the preferences of practitioners leading to a provisional 'schema for innovation' for a construction context.

[Figure 2]

Innovation Analysis

The BIM Risk Library project commenced in 2019 under the Discovering Safety research programme: a collaboration between the Thomas Ashton Institute (TAI, 2020), the University of Manchester and the Health and Safety Executive (HSE), UK regulator of workplace health and safety. Aiming to assist design and construction professionals to better manage health and safety via proactive use of digital technologies and mobilisation of information resources via a Prevention Through Design (PtD) approach (Yuan et al. 2019), research work resulted in a novel BIM-based tool developed within a commercial cloud-based platform (the BIM Risk Library). Four different companies, with a total of six separate construction projects partnered with the research project. Each project agreed to use the innovation, formalizing their commitment via signed collaborative agreements. The projects had an average duration of four months, and ranged in type (i.e. residential; industrial; commercial; infrastructure projects). By way of illustration, a screenshot of the BIM risk library tool is given in figure 3.

[Figure 3]

Separate work activities of the BIM risk library are now examined in sequence, as shown on figure 2.

Steering Committee Formulation

A Steering Committee was setup for the BIM Risk library composed of research project stakeholders. A primary source of membership was the BIM 4 Health and Safety Group (BIM4H&S): a UK industry group focused on digital technologies to improve construction health and safety. This group was instrumental in work leading to the industry standard PAS 1192-6: 2018 'Specification for collaborative sharing and use of structured health and safety information using BIM' (BSI, 2018): a working link with this group therefore being important as the innovation addressed digital technologies to improve construction health and safety. Frequent communication with the Steering Committee membership ensured that both *general understandings* and *practical understandings* of the innovation were discussed openly from an early stage. As research team ideas regarding the innovation evolved, these could be bounced off Steering Committee members; such interactions being an essential social aspect of innovation development. *Rules* around innovation use were also discussed and clarified with industry figures in a collaborative way at meetings. Amongst the questions asked were: how would the innovation impact existing project ways of working? What training and instruction would be provided? And how long would the innovation be mobilised? How could data be drawn from live projects and anonymised? These practical questions were critical for the further development of the innovation. The Steering Committee were consulted are regular intervals through the research project; the link being vital for *understandings* and *rules* of use to emerge.

Ontology and ERIC matrix

A foundational idea of the BIM Risk Library was formulation of an ontology to map out the elements that make up a risk scenario requiring specific treatments: the ontology concepts being rooted in industry guidance and previous academic work in the field. Details of the ontology and matrix are provided in Collinge et al. (2020b). The ontology embodied rules regarding types of data to be collected and the relations between them. Validation of the ontology and matrix came from the Steering Committee and BIM4 H&S group, which again enabled *general understandings* and *practical understandings* regarding the foundational ontology and its` conceptual underpinning to be reviewed, and confirmed as valid. The research team made notes of such discussions at the time for future reference.

Industry Workshops

The ontology was mobilised in industry workshops to populate nine risk scenarios with relevant treatments. The workshops affirmed the validity of the ontology and the overall approach of the research; both *general* and *practical understandings* of the conceptual ideas being reviewed and discussed by practitioners at the workshops. It should be noted that no contracts or specialised procedures were required to set up the workshops: individuals joined through professional interest and commitment to improving construction health and safety. Resulting from the workshops, a dataset of 9 risk scenarios and 162 treatments were identified to eliminate, reduce, inform, or control (ERIC) the risks covering four different stages of the project lifecycle: preliminary design, detail design, pre-construction, and during construction. The industry workshops maintained and consolidated the relationship with project practitioners.

Prototype Innovation

The dataset of 9 risk scenarios and 162 mitigations provided the basis for the prototype innovation: the dataset being saved as a comma-separated values (CSV) file. At this stage of innovation development, it should be noted that *general understandings, practical understandings* and *rules* regarding the innovation had been discussed several times over with industry experts. *Rules* regarding innovation use had been captured in notes to be taken forward into discussions with software developers. Both positive and negative potential reactions to the innovation by designers and companies (i.e. *teleoaffectivites*) had also been remarked upon several times over in meetings. The research team recognised the importance of addressing these in the work going forward.

S*oftware development*

Following a review of BIM software providers on the market, one specific software vendor was selected and a legal contract set-up between research partners and the vendor so the ontology and dataset could be hosted on a BIM software platform via a specifically designed interface (figure 3). This important step would allow a sharing of the innovation with industry, facilitating further population of the library with data by designers working on multiple projects. The contract with the software vendor was vital to this task: an insight here being the need to reserve project funds for software development (if expertise/capability is not within the research team).

The software vendor contract formalized the *general/practical understandings* and *rules* of use of the innovation, previously discussed in workshops, meetings, etc. Therefore, the "sayings" around innovation use were formalized in written form: specific "rules" that were to be codified into interface functionality of the software. For example, the preference to present project designers with a series of optional treatments for different risk scenarios rather than definitive solutions was codified into interface use (see figure 3). Both *general* and *practical* *understandings* and *rules* of use of the innovation were later to be made explicit in a printable User-Guide for designers. *Teleoaffectivities* (emotive reactions to the innovation) could only partially be addressed during this stage of work as the research team and software developers attempted to predict possible positive and negative reactions when the innovation would be in use. Further activities needed to be done to address such issues.

Innovation Piloting

Having developed the prototype, it was necessary to pilot it to validate work completed and begin the process of collecting more risks/treatments. Piloting began in Summer 2020 with 4 industry partners and 6 projects. A dedicated support service was setup to assist pilot projects with any questions they had about using the innovation – this service assisting with *understandings* and *rules of use* questions. Whilst each pilot was uniquely different, they all shared a common commitment to identify risks and improve health and safety. It was through piloting that opinion of the innovation was collected, with positive and negative reactions being captured via informal feedback and a more formal survey and interviews. Piloting was therefore very important: changes and amendments to the innovation could be usefully actioned prior to a much larger rollout to industry. By the end of the piloting phase (June 2021), a CSV file containing 401 treatment prompts for 31 risk scenarios related to 11 different risk categories had been added to the BIM risk library. A number of legal artefacts were associated with the piloting work (figure 2). These are discussed in the following section.

Innovation Evaluation

Following piloting and collection of data over a 5 month period, an evaluation process was initiated. A questionnaire survey and interviews with users provided opinions about the digital innovation. The interviews allowed more detailed opinions of the innovation from industry users of the innovation to be captured. Table 2 gives demographic information regarding the survey participants and interviewees.

[Table 2]

The survey revealed that 85% of experts agreed or strongly agreed that the innovation could positively impact design decisions and support selection of appropriate treatments to mitigate health and safety risks. Although 13 is not a large number of survey respondents, the positive comments of construction experts validated the innovation. Furthermore, such a sample number aligns with the guidance of Hallowell and Gambatese (2010), who note the value of small sampling numbers, where a minimum of eight experts is recommended to validate a research proposition. Furthermore, interviewees perceived that adding safety information to a BIM model, and pinpointing risks added value to their safety management processes. Another benefit noted was the structured approach to inputting risk data and the opportunity for collaborative work which the innovation enabled. As part of the evaluation, *understandings*, practicalities of the innovation, *rules* of use and *teleoaffectivities* were all queried through questionnaire survey and interview questions. For further information regarding the innovation survey, see Osorio-Sandoval et al. 2021).

Publicity

The innovation was presented at several national and international events (e.g. Digital Construction Week 2019; BIM for Water event 2019) and subsequently, won two prizes (buildingSMART 2020; Construction Computing Award 2021): these prizes confirming the value of the innovation to industry. Publicity is a vital aspect for any successful innovation, providing opportunity to communicate positive opinions and teleoaffectivity emotions about an innovation to a wider audience.

As noted on figure 2, several legal artefacts emerged as innovation work progressed. Examination of the Collaborative agreements and Data Management Workflow provide evidence regarding how an enactment of a distinct “schema” for innovation delivery became tangible in written form and procedural guidelines.

Collaborative Agreements

Collaborative agreements between industry partners, the HSE and the University detailed specific information and instructions concerning use of the innovation and creation of the BIM Risk Library. These were approved by each party`s legal teams and signed by organisational senior executives. The agreements covered issues such as data protection and anonymisation of data shared with the library. Provision of free software pilot licences to cover the pilot period and specific terms/conditions regarding long term use of data were also detailed. Support to be provided to industry partners, including training and instruction to assist users, and plug-in development to facilitate innovation use with different software packages were also specified in the agreements. A Data ~~Management~~ Workflow (figure 4) visualizing the data collection process for the BIM risk library was included in the agreements. With the agreements we see a shift from innovation “sayings” to written formalisations of understandings and rules of use, prior to actual “doings” taking place.

As noted, the agreements formalise and make explicit the shared thinking around the innovation (i.e. general/practical understandings of it; rules concerning its` use) already established amongst stakeholders; an absence of shared thinking being identified as potentially detrimental to collaboration if not established (Aarseth et al. 2012). For innovation developers, obtaining formal agreement to use an innovation is crucially important, so the language used to compose the collaborative agreement needs to be worded correctly. The collaborative agreements meet the points noted by Lokuge et al. (2019) as being important regarding organizational readiness for digital innovation: namely, resource readiness, IT readiness, cognitive readiness, partnership readiness, innovation valance, cultural readiness and strategic readiness.

Additionally, the collaborative agreements brought order to the innovation process so that all parties know their roles and responsibilities going forward, facilitating the transformation of the digital innovation from a prototype to technology in use. The underlying parameters form part of an “enacted schema” for innovation delivery (see Discussion), facilitating a collective goal and creating a team ethos and general understanding of objectives (c.f. Uhl-Bien et al. 2007).

Data Management Workflow

Intrinsic to innovation development was the Data ~~Management~~ Workflow for retrieval, review, anonymization and uploading of data to the BIM risk library. This workflow (figure 4) was integrated into the Collaborative agreements and embodied in processual terms the *rules* and preferences of practitioners regarding innovation use on their projects. For example, the workflow details how risk scenarios and treatments inputted by pilot projects were to be retrieved periodically from the cloud by the research team to be anonymized by removal of sensitive or project-specific information. The overall workflow shows how data was to be collected in a non-intrusive way: this being an effective and important provision of practitioners using the innovation. The workflow was a necessary and informative device to re-assure practitioners how the innovation would practically function, and how data drawn from projects would input into the growing BIM risk library. It complimented and clarified information given in the Collaborative agreements: clear communication on how an innovation will function in the project management context being vital.

[Figure 4]

The workflow also enacting the preferences of industry by defining the operation of the innovation in a project management context: data security; non-intrusive interactions with practitioners; a finite timespan of work activity; an easy to understand plan of action all being clarified. These preferred preferences of innovation users can be understood as being part of the enacted schema for innovation delivery (Figure 6~~Table 3~~).

Discussion

The review of the BIM Risk library work activities, together with the collaborative agreements and data ~~management~~ workflow evidences the presence of Schatzki`s 'organisation of practice' concepts (general/practical understandings; rules; teleoaffectivities – emotive behaviours) that together characterise a distinct practice. The evidence indicates how "sayings" regarding ~~an~~ innovation evolve into "doings" via formalised agreements and contracts between parties. Such a transformation is necessary for companies operating in competitive and data sensitive environments. Therefore, whilst the digital innovation journey has been recognised as an "ongoing social accomplishment" pivoting around "negotiated interactions between the main parties" (Bresnen, 2009, p.931), a social practice analysis brings greater clarity to the processes occurring in terms of ~~the~~ human behavioural aspects underpinning an innovation. The findings enable further reflections on the existing literature in terms of theoretical and practical contributions.

Theoretical Contribution

The social practice analysis of interactions and artefacts associated with the BIM r~~R~~isk l~~L~~ibrary innovation align with the framework of innovation diffusion of Steiber and Alänge (2015): the five step process ~~of that model~~ (desirability; feasibility; first trial; implementing; sustaining) being evidenced on the BIM r~~R~~isk l~~L~~ibrary ~~project~~ in terms of the work activities followed. The social practice analysis adds a layer of detail to this framework in terms of how understandings emerge, rules are established, formal agreements are made and emotive behaviours manifest. With regards to Rogers (1995) six innovation-characteristics that matter for its` diffusion in a social system (i.e. relative advantage for the adopter; compatibility with existing system; complexity/difficulty to learn; testability; potential re-inventions; observed effects), the social practice analysis provided ~~tangible~~ evidence of how each of these are linked to shared understandings, rules and emotive behaviours. A key insight is the importance of relational conditions underpinning innovation use and ~~the need for~~ good working relationships between partners. That mutual dependencies can result in ~~instance of~~ friction, satisfaction or other emotive behaviours (teleoaffectivities) is a reality when using an innovation. The various work activities occurring prior to innovation launch established positive relational conditions (formalised via the collaborative agreements). The empirical evidence suggests that digital transformation is not the simple application of a new technology into a project context, but an all-round transformation of project processes that connect with management, business and organization methods. The paper illustrated how activities leading to innovation development together with the collaborative agreements and data workflow provided a solid foundation for effective ~~successful~~ innovation delivery.

~~It has been noted that t~~The interplay between the dynamic process of innovation use and more routinized processes of project management work (Bygballe et al., 2016) has been noted ~~is~~ as an important one. The paper ~~insights~~ illustrates how this dynamic can be played out: the BIM risk library Data Workflow~~Management Plan~~ (figure 4) linking to issues of importance for practitioners under pressure to deliver work to time and budget whilst minimising disruption to ~~existing~~ project processes. Innovation developers and practitioners need to enter into trustful relationships ~~in order~~ for innovations to be given a chance for success; legal artefacts like collaborative agreements enable innovations to be tested, developed and deployed in transparent ways. The insights from the BIM risk library ~~of the paper~~ enable the practice of innovation delivery to be clarified (figure 5) in terms of how “sayings” transform into “doings”. As a result, the construction context for innovation may be understood as a distinct “field of practices” (Schatzki, 1996, 2001) with its` own distinctive schema of “preferences and prescriptions” (Knorr Cetina, 2001) of developers and practitioners, as highlighted in figure 6. Reference to such a schema is useful for both technology developers and innovation developers addressing practicality issues.

[Figure 5]

Practical Contribution

~~Whilst it has been noted that d~~Digital innovations demand changes to working practices (c.f. Cicmil and Marshall, 2005), with new practices emerging as people coordinate in new ways (Cicmil et al. 2006; Sage et al. 2012). ~~, a~~A social practice analysis clarifies how this happens in actuality ~~practice~~ (in terms of understandings, rules and emotive behaviours). Such a study extends understanding of the decision-making processes managers use in the adoption of new technologies and ~~the~~ strategies used to deal with uncertainty (Mitropoulos and Tatum, 1999). On the BIM Risk library, industry partners signed collaborative agreements following extended periods of discussion with research partners, establishing their understandings and agreed parameters of innovation use. Deriving from the BIM risk library, ~~F~~figure 5 illustrates how such discussions formalise into agreements prior to innovation use. As indicated in figure 5, the practice of innovation delivery and its` associated sayings, doings and formalisations may be visualised to have a relationship within which the preferences of stakeholders are emergent, formalised and enacted upon.

If we follow Knorr Certina`s (2001) definition of practices as "recurrent processes governed by specifiable schemata of preferences and prescriptions", we can begin to identify an underlying schema ~~of preferences and prescriptions~~ for ~~digital~~ innovation delivery in construction. Analysis of the BIM Risk Library assists in such a process and adds a level of social understanding lacking in models such as the technology-acceptance model (TAM) that fail to recognise user acceptance over time (Liu et al. 2018). Figure 6 ~~Table 3~~ draws together insights from the empirical evidence to present an enacted schema for innovation delivery in construction. It is contended ~~that~~ the schema should be reflected and enacted upon in order to make an innovation successful in a construction context. Additionally, the schema addresses the three tenets of Havenid et al. (2019) in a recent collection of works on innovation in construction; these tenets being to shed light on the organisational processes within contexts of innovation in construction; to apply novel theoretical perspectives to empirical phenomena, and to recognise the temporal and spatial distribution of innovation as processual activities.

[Figure 6~~Table 3~~]

The figure 6 schema ~~able 3~~ notes the prescriptions and preferences of developers and practitioners for effective innovation delivery. ~~for both developers and practitioners.~~ Developer ~~P~~prescriptions ~~for effective innovation delivery~~ include clear definitions of the purpose and ~~/~~benefits of an innovation; clarity over roles/responsibilities of parties; clarity on ~~and~~ how the innovation will work/function. ~~The p~~Preferences note aspects which would support successful innovation deployment, including the social practice concepts of Schatzki and the need to minimize disruptions to project work processes. A developer preference would be the ~~Innovation developers should note the~~ importance of reducing negative emotive reactions whilst promoting positive reactions if possible. The ~~Both~~ collaborative agreements, ~~and~~ data ~~management~~ workflow (embodying general/practical understandings, rules and purpose of the innovation), and user guide emerged as the project evolved ~~;~~ at a moment in time that was ~~appropriate and~~ required for progression of the innovation. These artefacts of innovation embody the prescriptions and preferences of developers and practitioners. These are shown in figure X as emerging from the processes. ~~; t~~The various meetings, communications and work interactions preceding their creation were important in preparing ~~the~~ industry partners for the innovation itself and laying the groundwork for its` uptake.

~~**Limitations**~~

~~A limitation of the paper is that the insights are drawn from one single study of innovation delivery. Whilst single case studies can be criticized from a data limitation point-of-view, it should be noted that 4 different companies used the innovation on 6 separate projects over several months. Therefore, the data upon which the study is based is not insubstantial. Additionally, as the innovation has garnered attention and won awards, it is contended that the insights of the paper are useful and informative for industry innovators and the academic community.~~

Conclusions

The paper advances understanding of successful digital innovation delivery in construction project management through a social practice analysis of various activities and outputs associated with one innovative technology (the BIM risk library): i.e. discussions; legal agreements; innovation workflow; software artefact; user guide). A limitation of the paper is that the insights are drawn from one single study of innovation delivery. Whilst single case studies can be criticized from a data limitation point-of-view, it should be noted that 4 different companies used the innovation on 6 separate projects over several months. Therefore, the data upon which the study is based is not insubstantial. Additionally, as the innovation has garnered attention and won awards, it is contended that the insights of the paper are useful and informative for industry innovators and the academic community.

Additionally, ~~T~~the paper provide~~d~~ds tangible insights into how an innovation can emerge from context-specific interactions (e.g. industry workshops; software vendor negotiations; piloting work) ~~(Williams and Edge, 1996; Orlikowski, 2009)~~ where general and practical understandings of an innovation, rules regarding its' use and teleoaffectivities (emotive behaviours) are part of the discourse. Employment of Schatzki`s 'organisation of practice' concepts to examine the interactions occurring and the resultant artefacts shared between collaborators highlight the importance of understandings, rules and emotive behaviours in the innovation journey. Whilst the evolutionary nature of innovation development ~~(Linderoth, 2010)~~ was described, a distinct 'field of practice' for innovation delivery came into focus, with a 'schema of generalisable preferences' emerging from the social practice analysis (figure 6). Artefacts such as legal agreements, software product and innovation workflow evidenced how the innovation discourse shifts from verbal "sayings" to formulised agreements and contracts that embody the preferences and prescriptions of practitioners: the practical realities of innovation use being translated into a tangible schema prior to their "doing" in construction project contexts. The ~~research~~ findings complement existing frameworks for understanding innovation delivery in project management contexts~~, building on the work of Steiber and Alänge (2015),~~ and provide an extension to the body of knowledge on factors contributing to innovation delivery in construction.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available in a repository or online in accordance with funder data retention policies (https://www.discoveringsafety.com/).

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Disclaimer

The author reports there are no competing interests to declare.

Ethics Statement

The research obtained ethics approval from the University of Manchester Ethics Committee. Subsequently, informed consent was received from the research subjects.

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Figure captions

Fig 1. Framework for diffusion of innovations

Fig.2. BIM risk library screenshot

Fig.3. Flowchart of work activities

Fig.4. Data management workflow

Fig.5. Practice of innovation delivery

Fig.6. Schema for innovation delivery

Practical Understandings	Knowing how to execute desired actions through basic doings and sayings.
Rules	Formulated directives, admonishments and edicts; rules can be defined as “methodically applied generalizable procedures of action”.
Teleoaffectivities	Acceptable and enjoined emotions, moods and actions associated with certain practices.
General Understandings	Understandings or senses of general matters pertinent to goings-on in practices.

Table 1: 'Organization of practice' concepts (Schatzki, 1996)

Expert ID	Area of work	Experience in the construction industry (Years)
EXP-01	Design	45
EXP-02	Other (specify) *All stages*	41
EXP-03	Other (specify) *All stages*	40
EXP-04	Design	5
EXP-05	Other (specify) *All stages*	44
EXP-06	Strategic planning	15
EXP-07	Construction	33
EXP-08	Design	40
EXP-09	Construction	33

EXP-10	Construction	49
EXP-11	Design	33
EXP-12	Other (specify) *CDM Principal Designer*	35
EXP-13	Design	28

Table 2: demographic information of survey/interviewee experts

~~***Schema for innovation delivery***~~
~~**Prescriptions**~~
~~➢ Clear articulation of the purpose of the innovation and its` benefits.~~
~~➢ Clear definition of the roles/responsibilities of participating parties.~~
~~➢ Clear definition of how the innovation will work/function.~~
~~**Preferences**~~
~~➢ Provision of legally binding agreements between parties to ensure innovation is used/tested.~~
~~➢ Provision of education/training for innovation use.~~

~~➢ Establish general understandings, practical understandings and rules of innovation use.~~
~~➢ Minimise disruption to existing project work processes.~~
~~➢ Guarantee confidentiality and data security.~~
~~**For innovation developers**~~
~~➢ Reduce negative teleoaffectivities when possible.~~
~~➢ Promote positive teleoaffectivities when possible.~~

~~**Table 3:** Schema for innovation delivery~~