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INSTITUTIONAL SHAPING OF CDE IMPLEMENTATION IN BIM-ENABLED AEC PROJECTS

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SUMMARY: *The common data environment (CDE) for information sharing is one of the fundamental requirements for effective workflow management to harness the potential of building information modeling (BIM). While studies are replete on BIM from a technology adoption perspective, notably lacking in the literature is the understanding of the influence of institutions and their pressures on CDE adoption as an information management platform. This study aims to address this gap. Using the action research approach, a flagship university construction project in India was studied to understand the interplay of institutions and CDE adoption. Institutional theory was used as a theoretical lens to illuminate and analyze the implementation issues of CDE. The findings show that CDE implementation undergoes a series of transformations due to institutional pressures. The responses to institutional pressures are conformance, coupling and decoupling, and mutations. Insights of this study guide practitioners to be aware of the processes through which institutional pressures contextualize and transform the intended change. Accordingly, findings can help managers and public sector agents on aspects related to nudging and shaping the implementation of change through action strategies and tactics. The study extends the BIM adoption/localization literature by highlighting that institutional pressures modify the objectives of CDE. It theorizes the processes through which institutional pressures contextualize and transform a change agenda.*

KEYWORDS: *Common Data Environment, Building Information Modeling (BIM), Action Research, Institutional Pressures, Change.*

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1. INTRODUCTION

1.1 Construction project problems related to data

Construction projects typically suffer problems concerning information sharing. Some of the recurrent problems are tempering or forging data, unused data, obsolete data in time of need, wastage of time in finding the correct and "up-to-date" data, and rework when incorrect data are used, leading to material, labor, and time wastages (Hjelseth, 2010; Mayo and Issa, 2014; Wong and Fan, 2013; Zhang et al., 2022). With the increasing variety and volume of information, there are also challenges pertaining to sorting, analyzing, storing and retrieving data (Whyte, 2019). To streamline the information flow on projects, effective communication between stakeholders thus becomes one of the most crucial aspects of project execution. In recent times, these issues have been addressed with the help of digital workflows and digital information, which may have characteristics such as shareability, accessibility, remote searchability and updability, which in turn are transforming project delivery models. This is even to the extent that digital information becomes project deliverable (Whyte, 2019). The construction industry is in the midst of a significant transformation from codifying knowledge in documents to digitalization in enabling project delivery. Accordingly, the extant literature has argued the impending need to enhance processes and tools in knowledge development and learning, particularly in technology-based projects.

1.2 Role of data in BIM and introduction to CDE

Data occupy a pivotal position in enabling collaborative building information modeling (BIM) implementation and are pivotal in initiating and sustaining the derivation of manifold BIM-related benefits. Bradley et al. (2016) identified shortcomings in BIM utilization. The shortcomings are related to information integration, mismatch of business process with BIM process, and lack of framework on data usage on the aspects of generation, consumption, rights and responsibilities. The exchange of relevant data plays a crucial role from the conceptualizing phase of a project lifecycle. Such data play a more prominent role in the planning and execution phases, informing later asset operations and the decommissioning phase. The 'enormous number of interfaces' and the 'data transition points' bring complexity to model maintenance (Preidel et al., 2018). Then, the concept of a common data environment (CDE) is introduced to enable smooth information exchange over the project lifecycle. The Common Data Environment (CDE) is a platform that acts as a central repository for construction project information where workflow is enhanced by collecting, managing, collaborating, and sharing information (ISO, 2020). CDE pertains to shared models, project data, and team activity and communication (Preidel et al., 2018). This helps in reducing mistakes and avoiding duplicates (ibid).

1.3 CDE Ecosystem as a BIM technology enabler

ISO 19650 delineates the data environment as dealing with project management aspects and information delivery aspects (ISO, 2020; Preidel et al., 2018). The client's information needs and the BIM execution plan are two essential documents pertinent to CDE in the project management dimension (Lee and Borrmann, 2020; Ragab and Marzouk, 2021). Realizing these aspects, the level of detail in CDE increased as versions were updated, e.g., PAS 1192 version 2 to PAS 1192 version 3.

The CDE ecosystem and BIM adoption are strongly interconnected. CDE adoption is a new collaborative way of working on a project. In other words, CDE is the "standardized environment for exchanging BIM information (Radl and Kaiser, 2019)." Not only BIM but also CDE is an integral part of information modeling technologies used in construction projects (Losev, 2020). BIM models with federation among various project participants are considered level 2 BIM usage, while a seamless integration project information model contained and managed in a common data environment is considered level 3 BIM usage (B1M, 2022; Mason, 2019). CDE is the core for BIM elementary level of model development. However, CDE, in its broadest sense, covers collaborative tasks, as well as workflow, among stakeholders – between the teams and between the organizations. Thus, CDE encompasses a considerably larger scope than the model development coordination performed in BIM (Patacas et al., 2020). BIM skill sets, for example, are required for validating the model quality and increasing the quality of any 3D model. A CDE tool, on the other hand, is necessary when the goal is to have a high-quality workflow to accomplish a task. As a result, a parallel can be drawn between BIM and CDE with workmanship: BIM is a raw material, whereas CDE is concerned with the craftsmanship required to efficiently manage the raw material to obtain a quality product at the end. Hence, ISO 19650 mandates CDE.

1.4 The primary challenge with CDE

Undoubtedly, there is an increase in interest in applying BIM as a technology in tandem with information management systems such as CDE that could integrate and help the information management of technology solutions. BIM adoption has been progressing from data collection to information integration and then to knowledge management (Wen et al., 2021). In this process, designers have usually championed BIM adoption historically. Nevertheless, the architectural, engineering, and construction (AEC) sector is underutilizing BIM's potential (Ahuja et al., 2020). A significant cluster of recent BIM studies focused primarily on implementing BIM to study the problems and obstacles in the implementation of BIM (Wen et al., 2021). While the idealistic expectation is a progressive increase in the capability of BIM implementation, unplanned change causes a decrease in BIM capabilities for a prolonged period before they can reach the desired capability benchmark. Thus, change must be planned and monitored (Aibinu and Papadonikolaki, 2020). In doing so, clients, especially public agencies, face various challenges before they can induce the intended change after the first step of mandating BIM (ibid). Accordingly, we study how CDE tool-enabled BIM construction projects are implemented.

1.5 Institutional pressures on CDE-based BIM-enabled projects

Papadonikolaki (2017) found that context and culture highly influence BIM adoption. A step further, Saka and Chan (2020) concluded that the influence of institutional pressures on BIM adoption is an important aspect that has yet to be addressed. While implementing BIM-related tools, pressures could be exerted by various actors such as government agencies, competing firms, or organizational resolutions to embark on BIM (Wang and Lu, 2021). These institutional pressures are predominantly due to the external environment (Saka and Chan, 2020). The top-down approach, particularly steered or driven by government legislation (Jiang et al., 2021; Makabate et al., 2021), can be seen as regulatory pressure. Similarly, conventional contracts also need to be modified to reduce disputes while adopting BIM, indicating the need for a new or custom set of regulative pressures on AEC contractors (Ragab and Marzouk, 2021).

Therefore, in BIM-enabled projects and usage of CDE, the focus has been evident on the 'what' of the CDE and BIM by underscoring manifold benefits, but the process, i.e., 'how' of the usage, is far from fully understood. In particular, the literature lacks focus on when bureaucratic rules and mandates prevail over the contracting parties or actors. Since CDE-based BIM implementation tends to be affected by manifold institutional pressures, it becomes imperative to address the following question***: How do institutional pressures shape CDE implementation in BIM-enabled projects?***

In addressing this question, we embark on the following objectives:

1. To understand the kind of institutions and their pressures in CDE-based BIM-enabled construction projects

2. To identify and map the antecedents of institutional pressures

3. To identify the influences and results of institutional pressures on prevailing implementation mechanisms.

This question is addressed by blending action research methodology in a single case study. The focus is primarily on five contracting parties: the client, the contractor, the third-party quality control agency, the design firms, and the project management consultant. Concerning contributions, this study unpacks the process of how to implement CDE. It narrates the CDE localization-related process theory that is needed through the help of explanations from institutional work.

The rest of the paper is organized into seven sections. The next section reviews the literature on BIM and CDE, followed by the research methodology in section 4. The findings are presented in section 5, followed by a discussion, implications, and conclusions.

2. LITERATURE REVIEW ON BIM AND CDE IMPLEMENTATION

2.1 BIM adoption literature

The extant literature uses terms such as 'black box' (Lindblad, 2019) while referring to BIM adoption to emphasize the complexity of internal workings and the shallow understanding of the systems. Various studies have focused on concerns related to the perception of change, professional work practice changes, and effort distribution in relation to BIM implementation (Aibinu and Papadonikolaki, 2020; Akintola et al., 2020). Other studies have examined public sector agencies, contractors, or the alignment of the goals and objectives and their interface between public and private agencies. Vass and Gustavsson (2017) studied intra- and interorganizational challenges when BIM was mandated in Swedish projects. The organizational issues they uncovered are reforming work patterns, offering education and learning, defining a common BIM definition, assessing the financial value of BIM, requiring BIM in procurement, generating rewards, involving maintenance departments, creating new roles, and ensuring interoperability. By taking the public sector perspective exclusively, Lindblad (2019) investigated the function of the public sector using the sociology of translation theory. The findings show that the government's main approach is to mandate its usage but that this strategy would eventually face challenges due to competing policies.

2.2 Government-driven and industry-driven BIM adoption

BIM adoption is pushed by the government *(government-driven approach)*, e.g., Singapore and the United Kingdom, and driven by industry *(industry-driven approach*), e.g., the USA (Jiang et al., 2021). These two approaches may have fundamentally different structures of implementation and, thus, different responses from stakeholders. For example, market-driven approaches are marked with internal pressures (Saka and Chan, 2020). Additionally, the majority of AEC organizations, which are small and medium enterprises (SMEs), differ from large organizations in the rationale and speed of BIM adoption (Ayinla and Adamu, 2018). Furthermore, engineering consulting firms often derive/align the meaning of BIM from/with industry authorities (Rogers et al., 2015). In addition, originations would need to adopt a different strategic perspective when BIM is expected/mandated in a project as opposed to an organization volunteering itself to become a BIM pioneer and gain a competitive advantage (Wang et al., 2021; Wang and Lu, 2021; Won et al., 2013). The former case would have a need for a steep learning curve and can be subjected to many tensions, particularly when most of the parties are on a journey to improvise the conventional delivery as opposed to a middle-out diffusion approach, i.e., driven by large organizations (Murguia et al., 2021) – also called the industry-driven approach (Jiang et al., 2021).

2.3 BIM localization

An important insight from the literature is that the contexts are unique and influence causing differences in the perception and framing of BIM adoption (Delhi and Singh, 2017). Thus, BIM adoption undergoes a period of localization (Wang and Lu, 2021) while shifting to a new ecosystem (Delhi and Singh, 2017). In doing so, interactions of actors in the ecosystem need to be considered. This can be done through the process of analysis, adoption and assimilation within the firm (Wang and Lu, 2021) or even in a national context (Delhi and Singh, 2017). The bottom line is that the transition toward BIM must be properly engineered (Al-Yami and Sanni-Anibire, 2021). BIM implementation is often considered analogous to IT-supported change processes (Aibinu and Papadonikolaki, 2020). Thus, the inference that the organizational environment shapes IT artifacts during creation and usage (Sein et al., 2011) might apply to BIM deployment as well.

Researchers distinguish mere software acquisition from actual BIM adoption (Succar and Kassem, 2015). BIM collaboration has been observed with three patterns: ad hoc, linear, or distributed in ascending order of complexity. These three patterns are distinguished according to dimensions such as actors, processes, and products (Papadonikolaki et al., 2016). In the distributed pattern, the authors show that among various actors, the focused features of the distributed collaborative pattern are that BIM is a contractual requirement to the actors with BIM savvy strategic partners, with process necessities such as prescheduled BIM-related meetings and predefined colocation practices, and the use of common data environment, product based features such as compliance to one BIM protocol, model checking tools, information exchange types, and deliverable file types. It is important to note that the low-level BIM patterns, which are ad hoc and linear, do not use a common data environment as their modus operandi (Papadonikolaki et al., 2016), and distributed BIM collaboration has the highest number of BIM applications. Additionally, the distinction between BIM adoption and BIM implementation is important. The former is a decision to adopt BIM in a project or in the projects of an organization, while the latter is about implementing BIM in the required manner, such as the type (modeling, collaboration, and integration), the level of BIM (Level 0, Level 1, or Level 2) and a particular collaboration pattern (ad hoc, linear, or distributed) (Papadonikolaki et al., 2016; Saka and Chan, 2020). For instance, integration capabilities aim at using servers for the model or CDE environment to support real-time network-based integration across disparate systems by improving workflows through standards, protocols, and contractual agreements (Succar and Kassem, 2015).

The conceptual idea, which stemmed from the literature review, is graphically represented in Figure1.

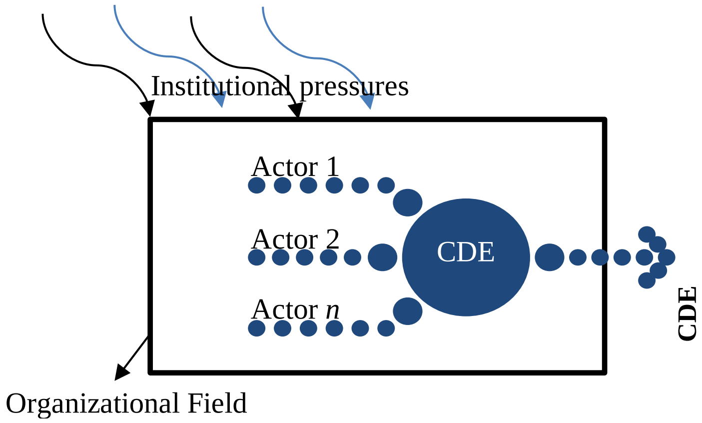

Figure1: Conceptual Idea.

The research question can be stated as *'how is CDE implemented in a public infrastructure development project*?' The conceptual hypothesis, as outlined in the literature review, is *that institutional pressures of the organizational field will modify the CDE ecosystem to cause localization, which in turn affects the efficacy of implementing the intended objectives*.

3. THEORETICAL BACKGROUND

In this section, we present the theoretical perspectives used to establish an understanding of the institutional shaping of a technology-driven information management tool called CDE, which is subjected to empirical testing.

3.1 Institutional Theory in Project Studies

Projects are characterized by diverse stakeholders and are representatives of their prevailing organizational practices. Attention to the institutional context of projects is increasing (Blomquist and Packendorff, 1998). Projects not only influence the context but are also influenced by the context. This is referred to as the embeddedness of projects (Giddens, 1984; Meyer and Rowan, 1977). Institutional theory is widely accorded for its explanatory power when institutional effects on projects due to embeddedness are the point of interest. Thus, institutional theory has been used as a rich watershed in the research of project studies (Biesenthal et al., 2017).

3.2 Institutions and Institutional pressures

Institutions are the regulatory structures, and the agencies of the institutions exert pressure and expectations and these forces are called institutional pressures (Oliver, 1991). In this manner, the rules, norms and beliefs that underlie institutions (regulative, normative, and cultural-cognitive elements and corresponding pressures) regularize the behavior of individuals, organizations, or networks of actors (Powell and DiMaggio, 1991; Scott, 2014). Since adoption responses of various organizations often differ among organizations in the amount of pressure they experience, in their characteristics, and in their location in the field, the explanation lies in the variable institutional pressures. Aspects such as regulative requirements emerging from laws, procedures or reporting, jurisdiction, cognitive beliefs or normative controls are recognized as the reasons for varied responses to institutional processes (Scott, 2014). One of the initial founding characteristics of this theory is that isomorphic processes such as mimetic, coercive, and normative processes lead an organization to stabilize, although change is the intention (Dimaggio and Powell, 1983). This is particularly true even for bureaucracy in the process of organizational manifestation in structure and behavior. In other words, bureaucratization and rationalization are informed by competitive or institutional forces leading to homogenous forms referred to as isomorphism. In response to isomorphic pressures, actors have strategic responses by active resistance through proactive manipulation from passively conforming to institutional processes (Oliver, 1991). While institutional pressures seek conformity, organizations enact strategic responses. The paradox is that the emphasis on conformance might result in divergence and vice versa. Thus, later studies revealed that institutional pressure related accounts of change rather than stabilization. Therefore, in contrast, Oliver (1991) established that organizations use their active agency to resist institutional processes leading strategic responses ranging from passive conformity to proactive manipulation. The general strategies for institutional pressures include acquiescence, compromise, avoidance, defiance, and manipulation. Thus, institutional pressures produce convergence (isomorphism) (Dimaggio and Powell, 1983) and divergence (organizational change) (Meyer and Rowan, 1977). In particular, the reasons for change include varying carriers, varying translations of institutional rules, errors in the application of rules, adaptations and innovations by users, and strategic responses by individuals, networks or organizations.

3.3 Institutional change

Concepts such as institutional entrepreneurship and institutional work have given fuller accounts of institutional change in many contexts (Battilana, 2009; Svensson, 2022). A theoretical viewpoint is that institutional work ties the creation of institutionally complex settings to the behaviors and interactions of the people who occupy them. It is founded on a practice perspective (Lawrence and Suddaby, 2006). Institutional theory has historically prioritized "embeddedness" over "situatedness". However, a change in the priority of institutional theory can be observed with interest in institutional work, where institutional transformation is now acknowledged as something that arises from and in practice (Hampel et al., 2018). Institutions are firmly ingrained (in) taken-for-granted rules, conventions, and routines providing actors with a model for how to carry out tasks, engage with others, and collaborate (Scott, 2014). Institutions are seen as shaping, giving meaning to, and holding structures, which in turn direct behavior (ibid). This entails taking into consideration the distributed agency of numerous players who are actively engaged in actions that have an impact on the institutional context to which they also belong. This essential aspect of embeddedness is that institutional change-related acts are located and temporally oriented, influenced by the past, present, and future (Baum and Oliver, 1992).

3.4 Factors leading to institutional pressures

Projects and AEC firms are by nature subjects of institutional pressures (Lundin et al., 2015; Mahalingam and Levitt, 2007). Researchers have found that government-driven approaches marked by external pressures tend to have subsidies to promote adoption by offsetting the firm's setup costs and pressures to adhere to the level of implementation (Saka and Chan, 2020). In public infrastructure projects, the mandate of BIM is increasing (Awwad et al., 2020). Thus, bureaucracy must be construed as a practice that is part of the organizational field, and it would dictate, alter or impede the adoption processes (Narayanan and Huemann, 2021). However, surprisingly, in another study, Cao et al. (2014) found that normative pressures related to standards and norms are not truly influential in BIM adoption in an AEC project. However, coercive pressures (use of force or threats) and mimetic pressures (habitual practices) are found to significantly influence BIM adoption. Tavallaei et al. (2022) dispute this conclusion by demonstrating that the main institutional pressure influencing the degree of BIM adoption in AEC organizations is normative pressure. Government pressures, cultural differences, and architectural practices are among the factors that affect implementation (Awwad et al., 2020; Faisal Shehzad et al., 2020). However, studies provided less clear understanding and lacked the depth that could address the apparent discrepancies, as shown above. Bureaucratic influences lead to issues such as institutional inertia among actors, i.e., a tendency to roll back to old practices after some time (Scott, 2014).

Furthermore, while the literature states that accountability and legal aspects have discouraged the direct use of a single shared model leading to a federally coordinated model between different AEC stakeholders (Preidel et al., 2018), the implementation is subjected to legal scrutiny from external sources to the BIM project ecosystem – again dictated by the vigilance or audit rules (Mahalingam, 2006). Thus, legal, contractual and cultural issues are highlighted to affect BIM implementation (Babatunde et al., 2021). In addition to these aspects, team and relationship-based barriers such as ‘silo’ working style and resistance to information sharing are noted to affect BIM implementation (Oraee et al., 2019). Similarly, Hajj et al. (2021) noted that the social behaviors of practitioners are responsible for the largest portion of implementation failures. On the other hand, globally, there is an increase in mandating BIM as a contractual requirement in public works. CDE is the starting point of level 2 maturity of BIM adoption that focuses on the 'federation' of data (Mason, 2019). Additionally, general contracting firms face complexity from the layer of enabling technologies, including BIM mandates, which results in conflicting logic leading to the problem of institutional complexity (Oti-Sarpong et al., 2022). This is because technologies will reconfigure the existing logic and arrangements (ibid). Zomer et al. (2020) focused on the activity system of BIM implementation and found that at the industry or organizational level, situated behaviors were recreated in accordance with institutionalized socio-historical constructions, including conventions, regulations, and the division of labor. Thus, they emphasize the process of re-enactment in the process of transformation. All these conditions imply the presence of various forces and motives (Dimaggio and Powell, 1983) for adopting the CDE tool and BIM technology in construction projects.

Adding to Vass and Gustavsson (2017), studies on BIM adoption and implementation must understand how the CDE-based BIM ecosystem responds to institutional pressures in public project contexts where there has been no prior systemic BIM adoption and there is no positional power to force change across a portfolio of projects. In contrast, when the government requires the use of a specific technology through a mandate, it is generally a demand or use of positional power rather than collaborative bargaining. This results in different attitudes of actors, and thus, a study on aspects such as rules, practices, policies, work culture, and information transmission protocols, among others, is inevitably essential. The present approach in this paper of no prior systemic BIM adoption and no positional power to force change would be midway between government-driven and industry-driven approaches and is relevant because such positional power and mobilization capability would not prevail in vanguard projects or pilot projects. Such projects might be viewed with much skepticism and encounter covert barriers in due process. Moreover, there would not be much resolve or message that such change is definite in the future. Therefore, Vass and Gustavsson (2017) recommend that project-based studies address these limitations in enhancing understanding, and the current study responds to this call. All notable studies thus far, such as the above, have focused on organizational cases but neither specified that bureaucracy was considered nor did their respondent profiles indicate so.

4. RESEARCH METHODOLOGY

4.1 Action Research and Case Study Methodology

This research sought to examine how institutional pressures impact the execution of a public infrastructure project that the authors can access, potentially influencing its course of action. Accordingly, action research is a suitable research methodology. This is consistent with the premise of action research to induce change while attempting to incorporate it. New knowledge is generated in this process (Lewin, 1946). Action research’s epistemological position is knowing through doing and applying discoveries. Additionally, the ontological orientation is that states of reality are dynamic and changeable through human agency (Bradbury, 2015).

Some characteristics of action research are that a researcher works in close collaboration with the project or organization, aiming to address the practical concerns and the research goals (Love et al., 2012). Thus, in a continuous and dynamic setup, theory informs practice, and practice refines theory. The philosophical considerations are that a researcher interferes (is positioned within the influential sphere) with the natural phenomenon where 'human-human' interactions happen. This is a mid-way between positivist and interpretivist paradigms (Saunders et al., 2009).

The five phases of action research are diagnosing, planning, acting, evaluating, and articulating the learning (Azhar et al., 2010; Love et al., 2012). These five phases are cyclical as shown in Figure 2. The identification of the key research concerns is referred to as diagnosis. The aim for change and the approach to change are established through action planning. The previous stage's planned actions are put into effect in this step. After the actions are taken, the collaborating researchers and practitioners evaluate the outcomes. While the phase of describing learning is the last to be completed, it is frequently a continuous activity. Continuous reflection occurs at every stage of the study, leading to comprehension and the abstraction of new knowledge.

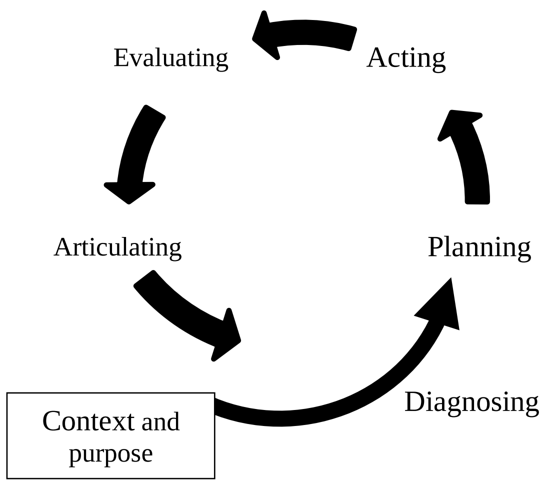

Figure 2: Action research process.

Action research is combined with or embedded in other methods, such as case studies (Svejvig et al., 2021), since it is not considered a single methodology but a 'way of working together to conduct research.' Thus, our study fits into the frame of 'action research in a case study' (Svejvig et al., 2021). Concerning the selection and number of cases, Yin (2014: 47) presents five rationales: when the single case is a critical test of a significant theory, a unique or unusual case, a typical case, a revelatory case, or a longitudinal case. The nature of the project (i.e., scale, actors involved, and the vision of using CDE in a BIM enabled project, and access of author(s) to the project makes this study unique. In addition, the public agency used this CDE tool for the first time (first project). This sets it apart from the CDE BIM adoption in privately built private infrastructure where different kinds of institutional pressure may appear from the privately built public infrastructure under the aegis of any other project management consultant (PMC) where there is a possibility of deep-rooted institutions. These reasons establish the case of being unique, exceptional or exemplary. Furthermore, there is a lack of comparable case studies, making a single case study the only option. Accordingly, we selected our case study. Additionally, access to all data is naturally granted to us, thus preventing the possibilities of misrepresentation of information and having maximum access needed to collect the case study evidence.

Action research has been used in many comparable problem settings. For instance, Parker and Mobey (2004) applied action research to a UK company to explore the organization's perceptions and attitudes toward risk while introducing electronic document management. Additionally, action research has been used in situations with inseparable and intrinsically connected activities of developing an IT artifact, engaging in an organization, and assessing it all simultaneously (Sein et al., 2011). What is more intriguing to observe in the extant literature is that action research, for the most part, is used in information technology (IT)-related studies, a field that closely matches BIM adoption (Aibinu and Papadonikolaki, 2020).

4.2 Overview of the project

The case study is a construction project developed for a university located in a south Indian state. The educational project executed is the case. In the university project that is studied in this paper, the challenges of using CDE and BIM have been an output of the diagnoses (see Figure 2). Accordingly, the research team, having insider access, planned the implementation of CDE-based BIM in the university project. After acting on the plan, evaluating the research team articulated the learnings that are reported in this paper.

The client organization that owns the project and, on whose behalf, various other actors lend their services is the context of the project/case. The client organization has many ongoing projects and is expected to have more contractually separate projects continuing in the future. The project contract reported in this study (phase 1 of campus development) was initiated in 2018. The total project cost (phase 1 is henceforth the project) is INR 597 crore (approx. GBP 59.1 million @ 1 GBP = INR 101). In summary, as of writing this case, the project has approximately 18 subcontractors, more than 100 vendor firms, and more than 3000 design drawings and specifications, with a mandate of LOD 400 requirement. A project management consultant was appointed to overlook the project implementation. A leading contractor is appointed for this project in the Engineering procurement and construction (EPC) model. Due to confidentiality agreements, metonymies in the upper case were used throughout the manuscript.

The project has at least six main stakeholders or parties who are attached to the project through an arm's length contract. The first is CLIENT's Engineering Works Department (EWD), the facility user and the project owner. Second, Architects/design consultants (hereafter referred to as ARC) are appointed by the EWD to develop conceptual designs of the campus, approve and vet the shop drawings, and appropriately modify the design should the site conditions demand so but only in consultation with the EWD and PMC. Two architectural firms are appointed – one for residential building designs and another for academic space designs. The third is the project management consultant, hereafter referred to as PMC. PMC operates with deep-rooted characteristics of bureaucracy. PMC is responsible for calling tenders, awarding tenders, ensuring timely delivery, and issuing sanctions to the contractors if there is a delay, milestone-based bills payments to the EPC contractor, and quality compliance and reporting to the EWD and the central government, which is the funding and granting authority of this project. This organization has a self-sufficient office established near the project site. They are related to the project CDE environment by having 20 EDC licenses. Fourth is the third-party quality agency (TPQA). According to the prevailing contractual structure of India, a TPQA is necessary to ensure the quality of the built assets. This agency is recruited based on competitive tendering procedures on a lump-sum payment basis for a period of 27 months (December 2019 to July 2022). Fifth is the EPC contractor. The lowest (L1) bidder in the EPC tender process is executing the project, i.e., establishing the assets within the scope. Sixth, the technical software team of EDC (metonymy used henceforth for the CDE software used in this project). By the time EDC was adopted, the drawings were 60% complete. A brief timeline of the project is shown below in Table 1.

Table 1: Timeline of the project.

Date	**Event**
2019 June	Change of procurement mode to EPC 3
2019 Aug	Start of the free trial of EDC
2020 Apr	Issuing protocols
2020 May	Approval of BIM execution plan
2020 May	Purchase of licenses by parties
2021 May	Renewal of BIM license
2022 Jun	Scheduled completion date (as per contract)

The representativeness of the data volume pertaining to meetings is outlined in Table 2.

Table 2: Meetings related to observations and data collection.

Sl No	Meeting Type	Participants	No of Meetings	Activity
1	Weekly Review Meetings	Research Team member, EWD, PMC, Architect, Contractor	108	RFI's Physical Progress, Quality
2	Monthly Review Meetings	Research Team member, EWD, PMC, Architect, Contractor	46	RFI's, Physical Progress, Quality,
3	Daily Site Visits	Research Team member, EWD, PMC, Architect, Contractor	465	Quality, Physical Progress

4.3 Data collection

We collected real-time field data on the change process as it unfolded. The process data were collected from three sources. Predominantly, continuous observations at each stage of CDE adoption are used. For instance, we analyzed a total of 495 closed issues until March 2021. Second, all the project-related documents are sifted. Third, open-ended interviews with each of the project's stakeholders are carried out. The first author interviewed the Chairman of the Engineering Works Department, third-party quality agency representatives, EPC contractor representatives, and PMC representatives. This is carried out in multiple rounds. The interview duration ranged from 33 min to 1 hr 10 min. The first round is in the middle of the project after observing the closed issues. The second round summarizes the learning before reporting in this paper. This is in accordance with the suggestion of measuring and analyzing process data by asking informants to interpret and verify incidents (Van de Ven, 2007). Furthermore, the respondents were asked to narrate their experience in using the CDE tool in the project, but probes were used to draw their attention when necessary. This is to confirm that the interview data reflect the reality/field observations when the change is promulgated. In addition, unearthing the logical reasoning of some resistances and their logic were facilitated by the interviews. To ensure unbiased and fair interactions, the author, who does not have any positional power or relation to the project, conducted the interviews. Given the long span of 2 years of observations, the interviews reached theoretical saturation, i.e., getting the same information with no new insights with a smaller number of interviews. These interviews were recorded and transcribed verbatim and were quoted in the results section to justify the drawing of inferences/learnings.

5. FINDINGS

5.1 Status Quo and Motivations of Change

5.1.1 The rise of challenges

Until July 2019, conventional communications were used in the initial stages of the project in coordination meetings. The client organization faced challenges in issue tracking, where the client was not able to understand the important issues and could not provide timely resolutions. This also led to delays, and thus, the second motivation was to avoid delays in various works/tasks. The client perceived that by tracking issues, they could enforce accountability on the concerned party, which is the third motivation. All these are to ensure the fourth motivation, which is to be effective and productive in meetings by being focused. This is also about being proactive in upfront avoidance of issues among the contracting parties, and a meeting is a time when the issues are closed. This can be contrasted with the earlier meeting styles. They were reactive, and so a meeting was the starting point for resolving issues. It used to take some days after the meeting to find the solution or solve the raised issue. In the proactive mode after adopting EDC, the parties came prepared, and the meeting is the endpoint most of the time for that issue at hand (unless it requires more time for any design change). We explain this below.

The project has diverse project teams, namely, architecture, structure, landscape, plumbing, electrical, and mechanical. In addition, the client has engaged a third-party quality assurance service to assist in the monitoring of day-to-day activities to ensure compliance. The project structure and the BIM management structure are given in Figure 3. The arrows in Figure 3 indicate the flow of information and delineate the contractual boundaries and links of various parties. For example, TPQA reports to EWD but does not have a contractual relation with PMC and EPC contractors, as shown in Figure 3. In principle, the TPQA must have no interaction or communication with the PMC but must only report to the EWD. In other words, the TPQA intimates the EWD on various lapses in the site, and the EWD will inform the PMC to take necessary corrective and punitive actions against the EPC contractor. It is mandated by the government for public projects. However, the TPQA has no administrative authority over the EPC contractor and the PMC.

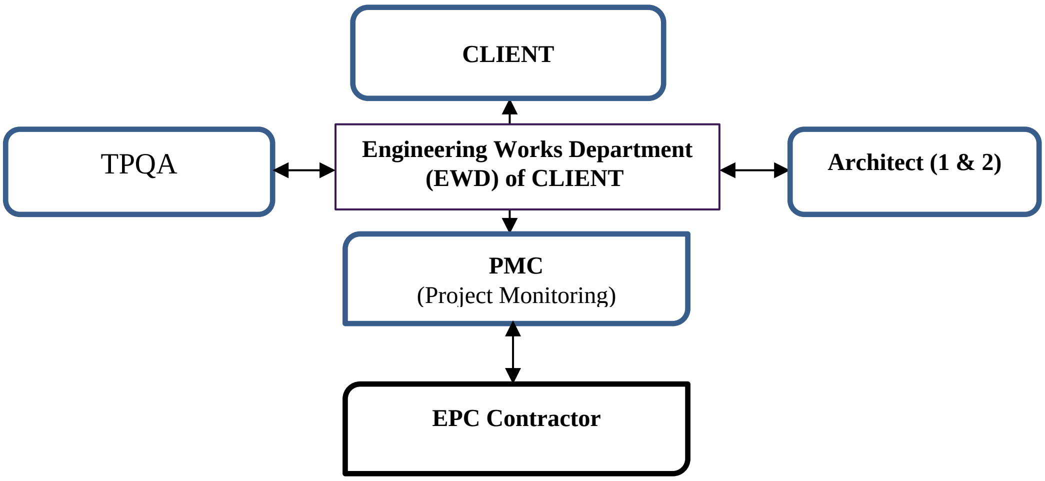

Figure 3: Contractual structure and information flow in the project.

The meetings were prone to frequent blame passing between Architect and PMC. The EWD started to see the issues of blame passing when the project had three project participants, i.e., EWD, ARC, and PMC, working on the drawings for the project. Coordination between the mechanical, electrical, and plumbing (MEP) trades is crucial to the constructability assessment process, and this is one of the major points of friction in communication. The representative of the EWD stated:

Because multiple contradicting statements were received from various stakeholders, there would be a single truth which we could not find […] when the project communications were done in an unstructured manner through email communications. In addition, we find it difficult to unearth it.

These prevailing reasons motivated the client organization to understand the adoption of a CDE solution to facilitate collaborative and effective project execution. CLIENT decided to operate with cloud-based EDC licenses. EDC is a module developed by a global brand that develops cloud-based solutions aiming to connect workflows, teams, and data to help build better. In its inception, EWD's prime motive was to manage documents alone. The client has mandated the use of a Common Data Environment (CDE) in the educational campus development project as a first step toward BIM use. Another motivation for using CDE is that it is much easier and intuitive, with minimal to no training required for the team to get started compared to other BIM tools and systems.

5.1.2 Initial thoughts of change

At the time of project execution, there are no concrete measures toward BIM implementation at both the federal (India) and state levels. Thus, the chosen case is a vanguard educational project. Although the federal procurement rules apply, the client exercises a certain amount of freedom to frame the contracts and policies according to their requirements. However, the lack of domestic BIM data exchange standards was expected to pose challenges while executing the project (Lee and Borrmann, 2020). Thus, the project must generate its own standards iteratively or rely on internationally available standards such as the Publicly Available Specifications (PAS 1192) and ISO 19650 Part 1 and Part 2. Thus, the project adopted the institutional work of mimicking frame to embark on change. Mimicry is defined as integrating new practices with established systems of accepted practices, technologies, and guidelines to facilitate adoption (Hargadon and Douglas, 2016). Thus, the whole CDE adoption process in this project started with mimicking the standard practices to enable understanding and use of new structures.

The CDE capabilities were progressively adopted in the BIM project. The initial setup for CDE adoption was derived from the standards, namely, Publicly Available Specifications (PAS 1192), ISO 19650 Part 1 and Part 2. The BIM champion recounted that as

Since different data types have to be there for a typical construction project organization for its smooth communication, we worked out the project folder structure even before we developed an MEP (Mechanical, Electrical, and Plumbing), with all access restrictions for the stakeholders, for example, TPQA owns TPQA folder, they have got the permission to do whatever they want in that.

The BIM championing team conducted feasibility studies and trial runs on various open-source software to finalize a suitable CDE tool. Then, the change was deliberate by the CDE champion who intended the change. A team from the software developer was on board within the project CDE environment for a brief period to facilitate the adoption process and training to some extent. The developer's software team is removed after the initial period to maintain the confidentiality of the project details. The TPQA used the EDC mobile app to record and monitor the site activities' quality aspects through a checklist. The client used cloud-based communication with project stakeholders.

The prevailing provisions (British Standards Institute, 2016; ISO, 2020) refer to the CDE environment as having six critical aspects embedded in the platform for smooth operations. These are filtering, workflows, communication, version management, rights administration, and status management. This six-dimensional conceptualization of CDE was adopted for the study. First, it concerns the extraction of desired information. Since the significant benefit of CDE is that it constantly aims to make stored data available to all stakeholders, filtering enables the prognosis of issues, queries, and retrieval without getting bogged down due to the volume of data in the software interface. Second, workflow aims that every communication occurs within the CDE environment, and each project participant has up-to-date information about the project. It has structured and unstructured information collected, managed, and disseminated across parties. The workflow has two critical components. First, it has embedded metadata that is driven by status codes. Second, it is governed by a workflow protocol that defines how information is transferred, retained, and accommodated. CDE can potentially replace the conventional printer or email correspondence related to project delivery. This CDE aims that every correspondence happens with the CDE transmittals. Third, project communication aims at supporting the assignment of various tasks to the concerned parties or persons in addition to facilitating the exchange of information by using comments and requests for information facilities within the CDE. Fourth, as communication makes revisions and improvements possible, version management enables the archival of old versions and the creation of a new and latest version. This avoids the hassle of locating the latest and updated file after the necessary amendments from various parties. This also addresses the possible legal questioning on variations. Fifth, the right administration ensures that each project participant is given the necessary rights. The rights broadly include view/edit/view and edit, and finally, delete possibilities. The project structure governs right administration. Sixth and last, status management is essential as, after a series of changes through a request for information and comments/corrections/and suggestions, the final shared version would be published and archived. Archival involves storing older versions but transferring the last version to an asset information model. All these moves within the CDE are called status management.

With the adoption of EDC, various parties are at different levels of the organizational field and are facing different types of institutional pressures due to the EDC mandate. The TPQA is subjected to the contractual obligation of adoption of EDC, EPC has faced an indirect coercive mandate to comply with EDC, and PMC is not subjected to any kind of coercive pressure by the EWD but has inertia due to habitual practices that can be seen as normative pressures. Similarly, architects were also subjected to the indirect coercive mandate. These are narrated below.

The design consultants were already on board before BIM was adopted. Even though the contract document specified that the design should be given as 3D BIM models, given the lack of a detailed contractual binding, the architects were slack in compliance, and EWD could not exercise any contractual control. However, the project benefited due to the change of procurement mode to EPC 3. Federal directive dated 2018 stated that all projects over INR 100 crores (approx. GBP 9.8 million @ 1 GBP = INR 101) must go through EPC regardless of the stage. They called it EPC mode 3, meaning the contractor performed the left-over design. Accordingly, in the project, 90% is done by the contractor. Therefore, using this as a nudge to shape the adoption, EWD asked the contractor to develop a coordinated BIM model for all the design documents, which was supplied along with the tender notice. As the work progressed, EWD issued a note (office directive note dated 06 April 2020) that specifies a level of detail that is required for their 3D models. As EWD could not amend the existing contract with ARC, they used nudging to the EPC contractor to achieve the same goal.

5.1.3 Championing the change

The CDE champion framed the penetration by an **episodic training strategy** to garner acceptance even on the simple changes. The training sessions were positively received but not on every capability of EDC. For instance, the CDE champion told the TPQA team that *"there is a tool to help you monitor the quality of the projects. If you want, we can help you."* This narrative of showing implementation intentions helped the TPQA come on board without resistance and looking for alternatives. There is also a secondary influence because they are contractually bound to use a digital tool to monitor the project - not necessarily EDC. Similarly, training episodes were conducted for PMC to facilitate the adoption of EDC. However, PMC resisted some EDC capabilities by not adopting the change but continuing their traditional way of functioning. For instance, the PMC was accustomed to manual coordination checking on 2D drawings. To initiate the change, the CDE champion of EWD encouraged the PMC to use clash detection using EDC and Navisworks. However, they resisted performing clash detection in the EDC. The stated reason was that they were habituated and more comfortable using Navisworks (which is not an EDC tool) than the EDC, showing the presence of institutional inertia.

The EDC ecosystem's adoption level is proportionate to the level of perceived benefit. For EWD, EDC offered a mechanism of work culture wherein the EDC platform provided access and visibility of all the project documents even without the software being installed on the computer. For PMC, document management that facilitates version control and raises issues in the drawing to the concerned parties was most helpful. For the TPQA, the ability to raise field issues of noncompliance and verify the drawings through their mobile app was quite encouraging and facilitated their willingness to adopt. The team recounted their experience as follows:

[…] our company was very much happy to take it, and the company decided to run this project with them. Recently, we have quoted another similar project, which is also going to have CDE in that. So, our company looks very positive in using EDC because this gives us a lot of flexibility in reporting, rating reports and inspection and other things. It becomes very thorough and easy.

For the EPC contractor, the experience met the expected return on the investment. As per the contract, the EPC contractor must provide a fixed number of licenses to the PMC and the client. They were also expected to be connected to the CDE medium as part of the contract. Nevertheless, the number of licenses was not mentioned. Furthermore, EWD has renewed the CDE SOFTWARE (CDE Document Management Module) license for another three years as they see use in further expansion (Phase 1B, 2) projects. However, EPC contractors prefer to renew it yearly, as their tenure is less than three years (in May 2021). Hence, the EPC contractor became a communication bottleneck among the key stakeholders due to a limited number of licenses. The EPC contractor reflected it as

[…] Therefore, we have a few licenses. Then, it becomes a communication bottleneck for us again. […] anything that comes through, we have to filter and send it to the concerned people. Yes, it is because all the information is coming to four people. Out of which, two licenses have been given to the BIM modelers and coordinators so that they can get their job done [addressing RFIs]

6. PROCESS MODEL OF CDE LOCALIZATION

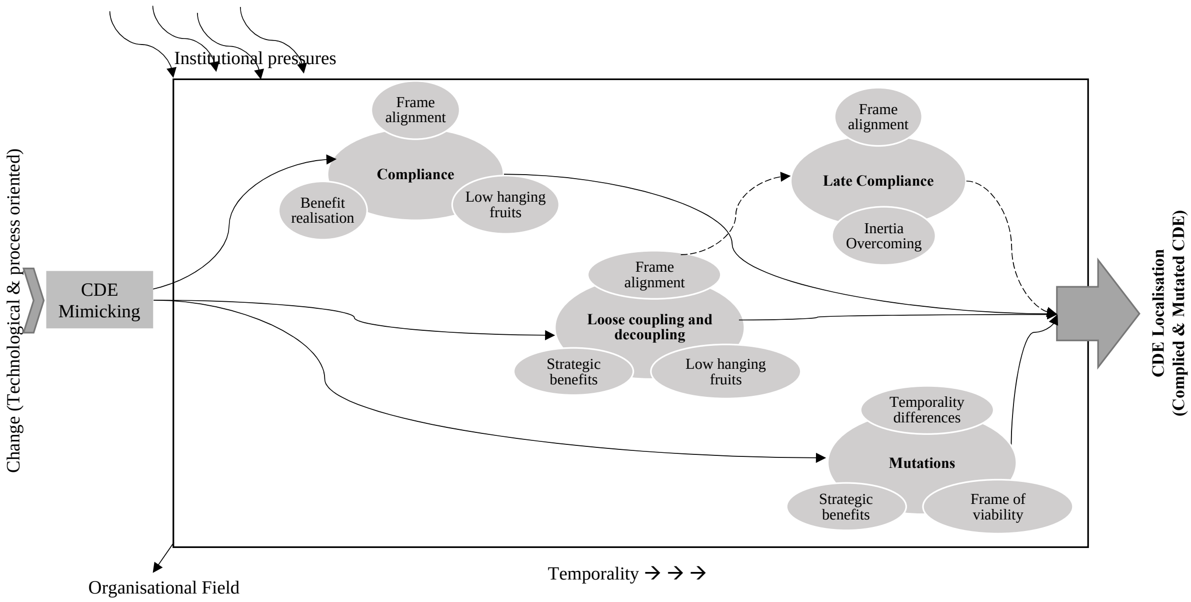

Figure 4: Process model of CDE localization in public infrastructure delivery.

The analysis of data indicates that the parties tend to conform to the change to some change initiatives and use coupling and decoupling to resist the change and even mutate to reconfigure the CDE-based BIM philosophy. This made the intended change (adopting CDE) a locally configured CDE solution. Figure 4 shows the process model of the changes in the CDE dimensions due to various institutional pressures. On the horizontal axis, it shows the temporality and the time that various actors took in doing the process they have done while adopting the CDE.

6.1 Compliance

The project started to adopt 'version control' predominantly and as a document management platform. This is done through a brief training period for various stakeholders. The version management capability of the CDE is accepted and complied with, as it indicates a phenomenon of complying. All the parties agree that version management has been very effective in managing the revision processes. Similarly, the filtering capability is adopted because it indicates an effect of complying due to institutions. Filtering with this phenomenon is extensively used without any modification. We explain these changes below.

EWD and PMC extensively used the filtering features. The monitoring agencies could filter the necessary information before coordination meetings. The approach changes from reactive/blame-passing interactions to a proactive and precise discussion about the tasks. The meetings had an agenda compared to the unstructured meeting nature before adopting CDE.

This was stated as

The PMC Engineers, as well as EWD. We go with the agenda items because it is just a filtering exercise. I filter. Suppose we want a 'classroom complex' discussion, I filter out only 'classroom complex' related issues and RFIs, and I will go with their priority as well…. Therefore, most of the issues are resolved in a very streamlined way. Additionally, the metadata, such as why, what and where it has been struck for a long time, is also known to the stakeholders […]

PMC also noted

[…] We are not having any issues with the tool's ability to filter. It does well in its ability to filter by various parameters such as issue creator - who is holding the issue timeline of the issue, and location of the issue - that we are not having many issues.

6.2 Coupling and decoupling-based reconfigurations

The workflow capability of the CDE is modified by coupling the organizational structures emanating from the contractual boundaries. The workflow was modified to suit the contractual boundaries, and modified workflow protocols were issued to the parties. We explain these changes below.

The PMC team was initially sceptical about the change to CDE and insisted that it would try only at the top level. They reasoned that testing before introducing helps them to maintain the team's confidence. In this implementation phase, the top three executive personnel were connected to CDE, and they passed on the information within their organization through conventional mechanisms such as email.

The EWD representative recounted it as

At that time, PMC also desperately wanted to control the versions of the design emerging out of iterative design coordination. For example, changes are made by the architect, but they forget to change the version name in the title bar. This becomes a problem because two drawings have the same version numbers. Fortunately, this tool has version control.

This incident was recollected as

Only three of the executive engineers agreed to use the version control tool. They said that we three are the channels to spread the information within our department, and we will use our own email communication along with the tool according to our needs, but their true agenda at the executive engineer level was to check the functionality through a hands-on before they let their department to adopt the same.

During this phase, PMC still used emails containing the drawing attachments in parallel to upload the drawings within the CDE. The PMC team carried an additional burden due to a lack of trust/confidence to rely on the CDE interface. Later, it was recounted that version control helped the stakeholders retrieve only the latest update and facilitated knowing the precise change instead of struggling to determine the differences and whether it potentially impacted the tasks of a particular project team.

Similarly, in workflows, PMC was reluctant to adopt transmittals. Transmittals can handle potential legal issues due to their contractual implications. Knowing whether there is a version change is impossible if metadata is not generated. This is because transmittals were not used. The resistance can be seen for three reasons. First, it is due to habitual processes (showing the presence of institutional inertia) that were followed. The PMC of the case study is the oldest Indian Engineering works department established in pre-independent India, and no other public sector agency is as old as the PMC of our case study. It has habituated practices at its core, even in project monitoring processes. The EWD is not mandated to instruct PMC to change its habituation processes.

Second, PMC follows a **2-tier system** that cannot be accommodated in the CDE ecosystem.

[…] EPC supposedly wants to submit a shop drawing. As I am talking about the workflow in the BIM platform that can be implemented in the building path. Therefore, he will be submitting it to the assistant engineer. If the drawing requires some correction after this code, there is no option in this platform to ask the agency to submit a correction. The only available option is for the assistant engineer to forward it to the executive engineer level. With their accommodation that this correction is needed, then it should be rejected by the executive engineer. Then, I will only have the option to reject it. I also do not have the option to obtain clarification from the contractor or other stakeholders. Therefore, it is a rigid process flow in the tool. Therefore, it does not match our 2-tier system of governance.

Moreover, PMC practices are scrutinized by India's federal agencies, such as the Central Vigilance Commission (CVC). Thus, PMC was more concerned about those bureaucratic processes than embracing the suggested change.

Third, the conflict is because of authentication. The authentication mode is manual signature-based and requires physical archival of the same. This is mandatory for audit as other federal government agencies, such as the Comptroller and Auditor General of India (CAGI), occasionally inspect them. However, due to COVID-19, an office memorandum to all public organizations across India allowed PMC to sign digitally. It stated that a document would be deemed authentic if communicated through the personnel's official email ID. Thus, digital workflows superseded hard copy transfer, but only for a brief period.

The status management capability of the EDC has also undergone reconfiguration through decoupling. Instead of automated workflow status change, PMC adopted manual means to authenticate the change in status of various task workflows in addition to supplementing with attested hard copies. PMC resisted the automated process of status management. Instead of changing the status of shared information to published and archived status, the PMC team modified the publishing and archival process by taking it offline. The team sent a cover letter authenticated by the concerned authority and mentioning the status (published/archived). The team resisted using automated status management, which conflicted with their organization's standard operating procedures (SOPs). This is besides resisting the usage of transmittals.

The rights administration capability of the CDE was modified through **dense coupling**. This is due to contractual conditions and the need for private information. This has prevented a free flow of rights to all parties. In other words, layers of rights were administered to the extent that the same project has two versions to make the checklists discrete between PMC and TPQA.

Various parties have contested data sharing. This is finally modified by issuing a rights administration protocol. To some extent, the collaborative working style changed to a silo/individualistic working approach. EWD noted this as

[…] In a typical CDE, all parties know the information. PMC is habituated to the silos' working style. Therefore, why should others know what happens between the two as private information? They forget that it is a project document that is common. The contention was not to have 'view access.' The resistance is in workflow design. We requested the EDC to make it again a silo approach from a collaborative approach. They said that we are asking to change the philosophy of the tool itself. We asked for their suggestions for improving the adoption. Then, we introduced an artificial layer of restriction on the access controls to different stakeholders by introducing two project pages with two different workflows for this same project. I can restrict the contractor from seeing some of the folders, which is uncommon to the CDE collaborative working philosophy.

The PMC representative recounted the reason for the contestation as

[…] since we have a contractual relationship with the EPC contractor. We cannot disclose our communication with the architects to the EPC contractor. Because it may have other contractual implications. Therefore, we have used the permission control system to ensure that a portion of the communication is invisible to the EPC contractor.

Aspects that can potentially trigger change orders or extension of time requests due to design issues make public agencies vulnerable and have cost and **legal implications**. This is due to the extension of time and variation in the contractual clauses of the project.

The second aspect of rights administration is the necessity to supplement the CDE to accommodate the contractual separation of the TPQA and PMC while monitoring the project. The separation led to the creation of a parallel dummy project in addition to the original project interface to maintain the confidentiality of quality monitoring-related checklists generated by each team at the site. The TPQA reports the field observation-based quality checklist to the EWD in the dummy project, while the PMC issues the quality-related checklist in the main project interface of the CDE. The TPQA and EWD are the only parties that can view the checklists in the former case. On the other hand, the 'curated' checklists generated by PMC can be seen by both EWD and EPC. This separation also stems from PMC's intention to identify only high-priority issues and reduce the number of issues. This is also to minimize vigilance on the project's team members. As an illustration, a redacted version of the modified protocol for rights administration for BIM models is depicted in Figure 5. This was issued on 06 April 2020 by the head of the organization to all parties and was incorporated into the EDC ecosystem on 10 April 2020.

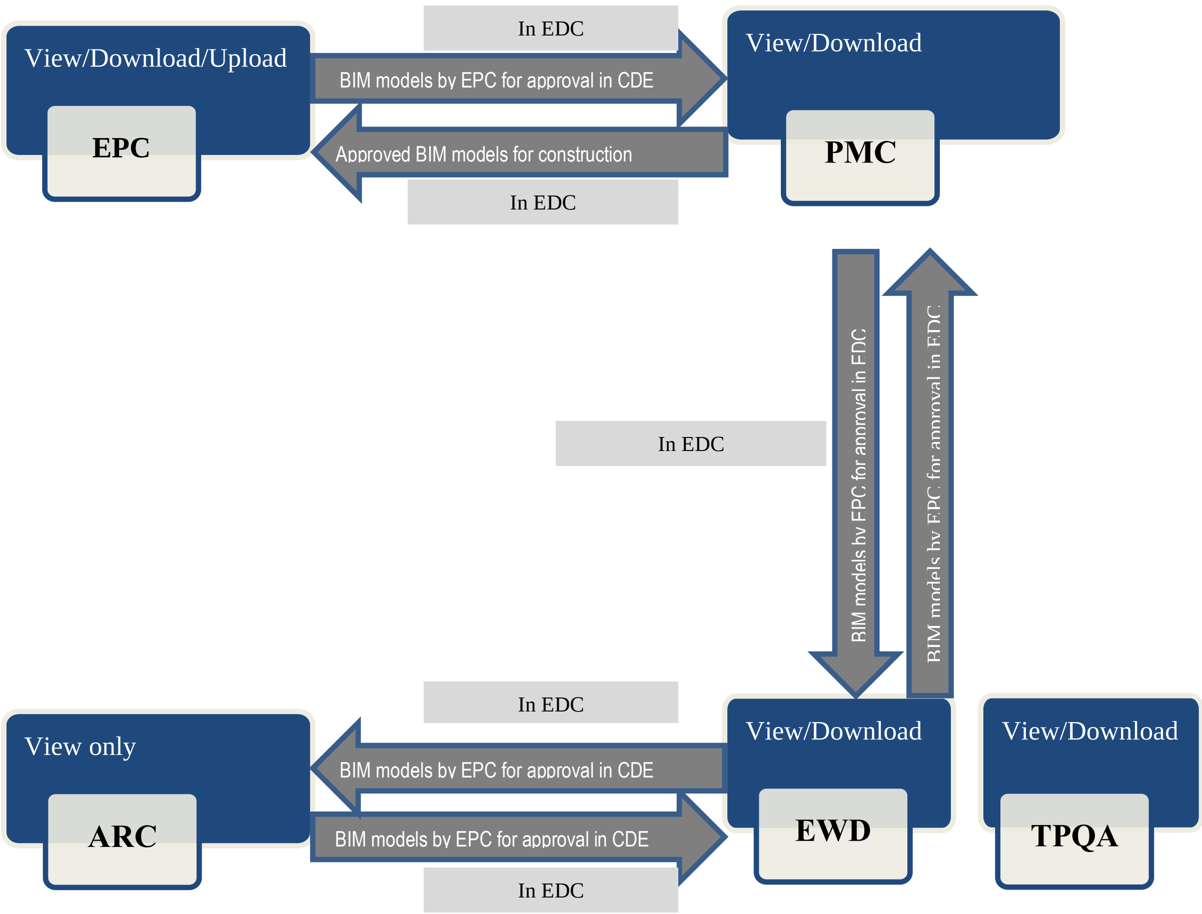

Figure 5: Modified document control protocol for information and models.

6.3 Mutations

The communications capability of the CDE is supplemented yet times and ignored in other instances, indicating a phenomenon of mutations sometimes very subtly. Emails were used to supplement communication in addition to CDE communication capabilities. Transmittals (communication data files) were wholly ignored for at least a year. We explain these changes below.

In addition to version management, requests for information (RFIs) and design modules were introduced. The project teams used the annotation feature, and the requested information or clarification in the drawings was uploaded into the CDE environment. Concerning the process of communication, PMC noted

[…] The documents will be frequently updated due to certain site conditions that demand design changes. Therefore, we are tracking through the tool because some drawings will have even 10-15 revisions. When executing such a large trail of documents, we found it difficult. Sometimes we might have to clarify some aspects of the drawing, i.e., partly have to be clarified. This revision control only tracks all these revisions through the EDC platform.

The teams rigorously used communication tools. This is due to the frame of benefits realization. For instance, after taking stock of the issues after a year of adoption, the project teams realized the efficacy of EDC in closing the issues effectively. The analysis of several issues (referred to as types and subtypes in the EDC) related to commissioning (5 issues), clash and coordination (100 issues), design issues that include building code, change due to site condition, client feedback, design per se (339 issues), general observations (45 issues) related to disciplines such as architecture, structure, landscape, plumbing, electrical, mechanical and others showed that all the issues were closed within the specified time, but sometimes up to 32 days period. A few that spanned beyond 32 days were intentionally kept on hold by the client organization.

Another aspect of the communication domain is raising checklists as a part of the quality management exercises. PMC insisted that not every field observation needs to be recorded in the EDC interface. In this manner, the PMC invoked the **frame of viability** to alter the EDC ecosystem.

PMC recounts this as

[…] we did not use the online checklist but preferred offline … we do not see much use in going for an online checklist. The reason is that most of the things will be settled immediately on the site itself - directly between the supervising engineers and contractors.

On the other hand, TPQA recounted it as

[…] here in quality management, the templates were created by us because we are the prime agency which uses EDC extensively. Therefore, we have created all the checklists that we require, and some of the checklists are yet to be created because all the activities have not been started.

By this time, we had a total of approximately 3700 checklists and started recording all the things. Then, when there is something that I just want to inform the stakeholders about, or there is some issue or something that is not as per the specification that is happening outside, then I can record it, and I can create an issue at the site. Immediately, the issue will be generated as a report, and it will go to all the stakeholders by email.

Thus, PMC was focusing on managing the amount of work from the perspective of record keeping, archival and standard protocols (a perspective of permanency), while TPQA is viewing it as a transient need of doing the work as obligated in the scope of their work with no burden of record keeping and archival. The client is also concerned about archival. This shows the difference in framing in the parties that caused subtle mutations in one case and compliance in another case.

Thus, the data show the mutation process **and contextual mediation** in CDE adoption. First, the adoption is shaped by **demonstrable benefit frames** to the project participants or their parent organizations. In this regard, the BIM champion had to use various strategies, such as invoking a contract clause, appealing a solution to the problem they encountered, or negotiating to try a change. However, adoption is still resisted when it conflicts with the contractual structure or the public organization's standard operating procedures (SOPs). Thus, the findings reinforce the altering script of the CDE ecosystem. The CDE adoption process observed an alternation of the prevailing organizational script, which confers legitimacy to regulatory pressures. This resulted in new and additional artefacts unique to this project.

Furthermore, when the CDE environment blurs contractual boundaries and the need for private (asymmetric) information between parties persists, the adoption of CDE is contested, and thus, its usage is **mutated**. This is contrary to what BIM advocacy would notice. The CDE thus becomes a bespoke artefact depending on the type of contractual structure. These aspects would apply to the sharing and accessing of the data. This would be different from the conventional understanding that CDE holds a wheel structure for information flow. Rather, the flow of information is again through the contractual structure even though CDE is adopted. Thus, contractual structures, particularly arm's length contract-based principle-agent relations that have information asymmetry at the core, can potentially negate the benefits of CDE. They influence the data sharing flexibility, thus impeding the full benefit of CDE adoption. Moreover, project members attempted to make connections but failed to have closer collaborations across various firms participating in the CDE ecosystem.

The findings also show that overall CDE adoption is subject to individual adoption of various tasks and capabilities of the CDE. The EPC contractor perceives a lower degree of economic gain, but regulatory pressure superseded the possible resistance to some features in CDE adoption. The institutional constituents of PMC caused resistance to some of the CDE capabilities. Thus, the contextual mediation of the communication tools is the reason for those deserted capabilities of CDE-based BIM. Therefore, the capabilities are not used 'as it is', and they are often modified or adapted before application.

6.4 Late compliance

However, with the passage of time, some of the capabilities of EDC that the actors earlier resisted were adopted, leading to compliance with the passage of time. This phenomenon of late compliance is associated with temporality. Given the time needed for the actor to adopt after learning, the CDE has been adopted. Therefore, learning became an essential contributor to compliance. Institutional pressures also helped settle standard operating procedure differences, which is the second reason for late compliance. Thus, the findings show that frame alignment and inertia overcoming are some of the processes that informed the maintenance of previously hard institutions but later led to CDE adoption. This can be seen as embedding and routinizing the changes. This can be seen in Figure 4, where compliance and late compliance are temporally separated. Additionally, compliance has not seen institutional work, but late compliance is associated with embedding and routinizing types of institutional work by actors such as EWD and CDE champions.

7. DISCUSSION

We focused on implementing a change in an environment with institutional pressures. This is done from the perspective of the implementing agency, which is the initiator and primary benefactor of the intended change. When the actors come from diverse characteristics of functioning and organizations ranging from deep-rooted characteristics of bureaucracy (Quinn and Kahn, 1967) to cross-functional matrix, the actors' responses to the institutions' pressures vary. Bureaucracy is heavily institutionalized and difficult to change, and actors that initiate change need to carefully consider strategies to implement and nudge the change in such circumstances.

While implementing CDE in the present BIM-enabled construction project case study, several government pressures ranging from mandates and subsidies that are incentives, legal demands, contractual factors, and social behaviours are observed. The actors' responses led to at least three process phenomena: complying and lately complying, coupling (decoupling, dense coupling, and loose coupling) and mutations. In addition to immediate compliance and late compliance (complying with the intended change after some time), coupling and decoupling, mutations from the CDE core ecosystem and the CDE ecosystem-related practices are observed. We also verify the discrepancy and confirm the effect of normative pressures in the localization of the CDE ecosystem (cf Cao et al., 2014) along with the finding that normative pressure is the prominent institutional pressure affecting the level of BIM adoption (Tavallaei et al., 2022). However, unlike institutional pressures being an effective tool for enacting systemic change and spreading BIM in the AEC sector (Tavallaei et al., 2022), they could also distort the ecosystem, as reported in this study.

Consistent with Weick's loose coupling idea, CDE adaptors must understand and accept circumstances in which policy plans conflict with organizational practices or vice versa (Weick, 1976). In adopting change such as CDE, which is subjected to institutional pressures, the project's actors adopt decoupling, followed by loose coupling or dense coupling. In particular, much of the coupling happens with the existing and age-old standard operating procedures and organizational inertia.

Concerning mutation, actors and entities tend to preserve their own identity. They sometimes do that with physical or logical separateness, using logic as an agent to resist the change. Environments impact organizations and can even infiltrate them, but they can also respond to these attempts at influence in novel and strategic ways. Organizations can occasionally resist, reduce, avoid, or reframe these demands by cooperating with other groups experiencing comparable pressures. There has been an observed mutation phenomenon. Contractual boundaries are the second principal reason for resistance and the leading cause of mutations. It is still crucial in CDE adoption in public infrastructure projects. Additionally, unlike private projects, the role of BIM actors who promote and ensure that the technology is valued and accepted (Bosch-sijtsema and Gluch, 2021) is negligible. In contrast, the role of client organizational championing is crucial in sustaining the goal of change.

The finding implies that when various actors with diverse interests act on change implementation, the implementing agency needs to be aware and realize the pressures, contractual boundaries being a case in point. When the frames of the actors and the change are aligned through mechanisms such as showing quick benefits and low-hanging fruits to the parent organizations, the contestations can be minimized, and the change can be possible. In cases where there is strong resistance to change, sustained efforts and systematic nudges are needed to ensure that change is made possible.

The study extends the BIM adoption/localization literature by highlighting that institutional pressures modify the objectives of CDE, which in turn would alter BIM adoption at a local level within the balancing push (forcing actors to adopt) and pull mechanisms (changing the CDE ecosystem to fit the tradition) underlined in the extant literature.

One of the previous localization studies argued that organizational global and local contexts and networks differ; therefore, analysis, adaptation, and assimilation are required (Bosch-sijtsema and Gluch, 2021). The multinational parent firm is localizing the practices in a country where they have a project. This is intraorganizational. However, the localization process theorized in this study is different. It is localizing the initial mimicry of standards to a mutated ecosystem due to institutional pressures.

The understanding of the influence of socio-historical constructs on BIM where the conflict and tension between situated and existing practices cause changes in the definition, production, and handover of information requirements through re-enactment (Zomer et al., 2020). It emphasized the content of implementation and their interactions. Considering the present findings, the re-enactment is contingent on the contractual boundaries and bureaucracy in public projects where much of the resistance emanates, leading to mutations.

8. IMPLICATIONS AND RECOMMENDATIONS

This study has important managerial implications as to how actors should deal with CDE adoption in BIM-enabled projects with contingencies such as historicity and multidimensionality, which is typical in a public project. Since studies have shown that BIM technology should be adopted using a bottom-up strategy rather than a top-down strategy to successfully manage change and cope with resistance to change (Arayici et al., 2011), we extend this understanding in terms of what happens in the case of resistance to change in an information management ecosystem that supports technology adoption. We open the process and suggest progressive adoption in increasing usefulness with various strategies over time.

Some of the inter- and intra-organizational challenges reported in previous studies (see Vass and Gustavsson, 2017), such as modifying working procedures, offering instruction and learning, establishing a shared BIM definition, assessing BIM's commercial worth, BIM requirements for procurement, and interoperability management, are but the challenges that are interlinked to institutional pressures. Previous research promoted the idea that the creation, use, and adoption of BIM by participants in the AEC sector are significantly influenced by public clients, both formally and informally (Vass and Gustavsson, 2017). This study continues the conversation by highlighting the process between the project actors when the ‘change’ is at the centre.

The case study showed that change implementation has a strong temporal dimension. This has implications for the temporality of the projects, as they are short-lived. Thus, short-term implementation goals that can be adopted in the projects are the benefits projects, i.e., the reaping of low-hanging fruits and problematisation can be used to advocate the change. In addition, cognition mismatch of technology on projects needs to be handled so that actors are on the same level playing field on what the technology is offered rather than having unrealistic expectations. Furthermore, change management and localization require shaping by aligning the frames to the existing pressures.

Based on the findings, the study has a few implications for theory. First, the study used institutional theory to demonstrate the effect of institutional pressures and how they influence CDE adoption in many subtle ways, mainly concerning public projects that work with arm's length contracting. The causal relation that institutional pressure affects the push and pull strategies is a novel contribution. In this vein, this paper contributes to the literature on BIM localization. While localization is argued to be the way in the literature, we showed how a local public agency implements CDE in its project. In particular, we found that CDE adoption is not straightforward but is shaped by institutional pressures, leading to a divergence from the intention. In terms of methodology, this study has used action research to understand CDE adoption. Action research unveiled the implementation problems in a much broader depth than any other engaged scholarship method would provide. In particular, the researchers benefited from insider access to the intended change, which gave much closer observation and inferential capacity than other competing research methods. This contrasts with many past studies where researchers were *external observers* of the phenomenon (see Wang and Lu (2021) for example). Thus, this study contributes to reflective professional practice and co-productive research logic in project studies (Ayas, 1998; Svejvig et al., 2021), as observed in the induced findings.

9. CONCLUSIONS

BIM adoption has attracted heightened interest in recent times. However, little interest has been given in the past to the influence of bureaucratic pressures on adopting and implementing BIM in general and CDE in particular. This paper reported the results of research on the implementation of CDE based on ISO 19650 in one of the upcoming AEC construction projects in India. This study adopted action research methodology and used institutional theory to analyze CDE adoption in a public infrastructure project delivered through the EPC mode. The study found that institutional forces lead to a succession of modifications in CDE implementation. Apart from conforming to the mimicked CDE ecosystem-based information management and practices, the parties tend to achieve late compliance after some time, use decoupling and coupling, and mutate to reconfigure the CDE-based BIM philosophy. This makes it a locally configured CDE solution.

The study also has a few practical implications. The study presented a rich account of the unfolding of CDE implementation from which practitioners can derive benefits. The study recommends that because bureaucratic pressures and practices are the most difficult to alter and might deplete the CDE advantages, governments should constantly focus on re-enacting organizational procedures to match BIM applications if they want to see more CDE adoption. Practitioners and policymakers need to carefully consider contractual relations while designing CDE modalities to obtain optimal benefits from CDE.

To address the study's limitations, such as studying only one project in an isolated institutional set-up, studies are needed with much broader and diverse cases that can confirm the presented theory. These studies could incorporate or control influencing factors such as the maturity of participants on CDE and BIM, the influence of contractual arrangements, e.g., public-private partnership models, design-build contracts, or alliancing, among others, which further contributes to and mediates the strength of the relationship between various actors. This helps delineate the influence of contractual boundaries, which causes mutations in CDE capabilities and adds strength to the theory and transferability of insights.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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