Developing Digital Project Delivery Routines Around Frequent Disruptions:

How Do AEC Organizations Respond to Disruptive Information Exchange Requirements?

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Abstract

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The unprecedented variation of information integration agendas in the architecture, engineering, and construction industry disrupts the development and maintenance of information exchange routines in firms. This research probed this important emerging phenomenon in three longitudinal ethnographic case-studies. The first case-study answered the question *"What types of disruptions do firms experience in working with custom information exchange requirements?"* and found that custom information exchange requirements can be disruptive in that they constrain technological and organizational settings and undermine the scope of work, sequence of actions, and timeline of enacting routines in practice. To understand organizational responses to such disruptions, the second case-study offered answers to the question of "how firms

perceive, interpret, and act upon disruptive information exchange initiatives in a project?", thereby revealing three reasoning mechanisms that underpin organizational responses: deductive, inductive, and abductive. With temporary nature of individual projects that limit opportunities to balance abductive and inductive reasoning (important for endogenous improvement of routines), firms are likely to identify and enact solutions that are temporary in nature, highly divergent from existing routines, and therefore, not durable nor effective in contributing to the refinement of information exchange routines.

The third case-study complemented these findings by answering to the question "How do firms perceive and respond to the surge of disparate information exchange initiatives in a multitude of projects?" This case spotlighted the shifting loci of information integration in firms, wherein the custom information integration requirements in individual projects undermine internal information integration among projects, portfolios, and operations in firms. This study also revealed that practitioners either separated custom and durable logics of their practice or they found effective strategies to meld them. Based on these insights, this dissertation conceptualized genericity-complexity trade-off in information exchange routines to explain how firms develop routines around the frequent disruptions. Generic routines facilitate addressing custom information exchange requirements with ad hoc and temporary responses in projects, while complex routines systemized, coordinated, and distributed responses within and among different projects and organizational constellations. This research discusses the implications of genericity-complexity trade-off in information exchange routines for internal information integration and knowledge sharing in firms.

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List of Abbreviations

AEC.....Architecture, Engineering, and Construction

ASI ..... Architect's Supplementary Information

BIM.....Building Information Modeling

BSI ..... British Standards Institution

CAD ..... Computer Aided Design

CBWS .....Cloud-based Work Sharing

COBie .....Construction Operation Building information exchange

FM.....Facilities Management

FMDS ..... Facilities Management Data Specification

FDR.....Facilities Data Repository

GC .....General Contractor

GSA..... General Services Administration

ISO ..... International Organization for Standardization

LNSD ..... Local Network Shared Drive

NASA.....National Aeronautics and Space Administration

NBIMS.....National BIM Standard

NIBS ..... National Institute of Building Sciences

OMR ....Operation and Maintenance Repository

RFI ....Request for Information

SER ....Submittal Exchange Repository

USACE ....United States Army Corps of Engineers

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Chapter 1 - Introduction

1-1 - Synopsis of Research Problem

The architecture, engineering, and construction (AEC) industry is information intensive due to the involvement of different participants from multiple technical and organizational disciplines, who generate, exchange, and work with a large amount of information in complex projects (Zhou, Goh, & Shen, 2016). However, inadequate information exchange, hampered by a lack of coordination and poor information integration, is the major reason for difficulties and inefficiencies experienced in design, construction, and operation of buildings and infrastructure (CURT, 2004). This problem leads to redundant efforts for data collection, re-entry, and validation for those who take part in projects and operate facilities and infrastructure. To put this into perspective, research shows that this poor information integration imposes tens of billions of dollars per year on stakeholders only in the U.S. capital facilities industry (Gallaher, O'Connor, Dettbarn, & Gilday, 2004). These significant inefficiencies in information development and exchange emphasize the ongoing need to improve information delivery regimes in the industry.

To tackle this issue, the industry has set forth the concept of "information integration" to leverage the advances in information technologies and promote sharing information in project networks by consolidating information from different parties, technologies, tools, and processes (Kang, O'Brien, & O'Connor, 2012). Different stakeholders have attempted to standardize information integration agendas in the industry by creating information exchange guidelines (descriptive and optional), protocols (prescriptive and optional), and mandates (prescriptive and obligatory) in different regions, markets, and projects (Charef, Emmitt, Alaka, & Fouchal, 2019; Kassem, Succar, & Dawood, 2015). Furthermore, heterogenous groups of owners and clients in the construction supply chain impose custom information exchange requirements on project parties to address their unique information integration needs in terms of contents, structure and format, exchange media and methods, technologies, and infrastructure (Abdirad, 2015). With this trend in the industry, AEC firms have faced an unprecedented variation of custom information exchange standards and requirements that impose disparate and potentially incompatible information integration agendas on their practice.

Evidence from the existing literature suggests that both the heterogeneity of information agendas and the fragmented information exchange practices in firms are, in part, due to how the industry operates as a loosely coupled system. In this system, firms have a temporary tight coupling in projects to adapt with project specificities while they keep a loose coupling beyond projects to manage and carry out internal work (Dubois & Gadde, 2002a; Papadonikolaki, 2018). In fact, because the industry often gives firms the slack to explore durable elements of their practice, each firm unilaterally creates internal routines to achieve consistency and efficiency across its loosely connected projects (Bresnen, Goussevskaia, & Swan, 2005; Dubois & Gadde, 2002a). Research shows that information development and exchange, indeed, has been an area wherein firms tend to establish internal regularities and routines (Harty, 2008; Harty & Whyte, 2010). However, this tendency to flexibly routinize internal information exchange practices juxtaposes with the unprecedented surge of custom requirements that firms nowadays experience in projects. Given its dual impact on productivity in firms and information integration among firms, understanding and addressing this emerging phenomenon is of both empirical and theoretical importance. Accordingly, this research aims to explore ***how this surge of custom information exchange requirements impact existing routines in firms***, and ***how firms perceive and respond to this phenomenon as they strive for maintaining their information exchange routines.***

1-2 - Theoretical Background

1-2-1- Organizational Constellations in the Construction Industry

Practice in the AEC domains involves different organizational constellations (e.g. industry, firms, project networks), wherein complex institutional and inter-organizational forces impact internal workflow in firms (Abdirad & Dossick, 2019b). This complexity of organizational constellations results from the evolution of construction techniques, products, and materials in the past century which led to a growing number of specialty businesses with their increased participation in temporary projects (Kalin, Weygant, Rosen, & Regener, 2011). These temporary interdependencies necessitate a tight coupling of project participants to focus on unique characteristics and requirements of each project. From a higher organizational standpoint, however, the couplings at the firm level are loose because (1) a project team rarely work together in more than one project (as each project often constitutes a new combination of firms), (2) requirements and activities in one project may not be applicable to or dependent on other projects (relative independency of different project networks), and (3) micro-level activities undertaken by a firm in a project are often independent of or blind to other firms across other projects networks (Dubois & Gadde, 2002a). Beyond the scope and timeline of individual projects, firms have a loose coupling as they become less dependent on other firms in how they plan and carry out their internal work. This becomes specially important when macro-level institutional forces in the industry give them minimal behavioral templates for practice (Dubois & Gadde, 2002a; Thornton & Ocasio, 2008). In fact, the temporary allegiances to project networks and flexible institutional norms creates a practice environment in which firms can independently establish internal routines in some scope of their work to enhance consistency, stability and productivity across their projects (Bresnen et al., 2005; Dubois & Gadde, 2002a).

1-2-2- Variation of Information Integration Agendas in Practice

The literature suggests that firms tend to establish internal information exchange routines in their practice because of the flexibility in institutional norms and often unrestrictive requirements they faced in their conventional practice (Harty, 2008; Harty & Whyte, 2010). This section overviews the industry trends that shifted the conventional information exchange practice; these trends gave rise to an unprecedented variation of information exchange requirements that undermined the freedom of enactment firms used to have in their projects.

Project participants often use different communication media (e.g. visual, print) and different symbolic and iconic representation means (text, graphics, and pictures) to express ideas and exchange information (Bretz, 1971; Tzonis & White, 2012). Historically, these ideas and information have contained a description of scope and characteristics of design and construction products in project specifications and reports (text) and drawings (graphics) (Kalin et al., 2011). In the past century, however, two important trends, (a) innovation in construction materials, means and methods, and (b) new digital information technologies such as computer aided design (CAD) and Building Information Modeling (BIM), led to the development of many new guidelines, protocols, and mandates that regulate communication and information exchange in projects.

With the evolution of construction materials, methods, and products, project documents and specifications similarly have evolved in complexity in terms of their content and organization. This resulted in a "mild chaos" when each individual, even within the same organization, used different methods to organize and identify project information in these documents (Kalin et al., 2011). This made finding and using information difficult for project participants since they had to work with documents that were inconsistent in terms of classifications, organization, and contents. These issues highlighted the need for standards and specifications that regulate the large amount of information in project documents to streamline information processing and exchange. These problems have been amplified by the evolution of information technologies and CAD tools in the construction industry. This is because not only does CAD-based representation and exchange of building information still require consistency in ontologies and classification systems (as the baseline for specifying and organizing design and construction information), implementing these technologies needs additional specifications to regulate how information of physical products must be digitally and visually represented, exchanged, and used in projects.

Since the 1970s, CAD developments have continuously improved and acceptance among design and construction professionals have continuously increased (Tzonis & White, 2012). With the proliferation of two-dimensional CAD, the industry faced another chaos concerning the different conventions in the creation, classification, and organization of digital CAD data such as naming CAD documents, organization of drawing sets and sheets, drafting conventions and symbols, and technical terms and abbreviations (National Institute of Building Sciences, 2007, 2016). In the past two decades, with the evolution of CAD tools and development of object-oriented Building Information Modeling (BIM) platforms, these software now support digital modeling of three-dimensional building components that can store heterogenous data useful for design, construction, and operations (Hubers, 2010). With these advances, digital models have provided the practitioners with affordances that support many innovative uses of digital information (e.g. for interference detection, energy analysis, engineering simulations, quantity take-off, model-based asset management; Kreider & Messner, 2013; The Computer Integrated Construction Research Group, 2010). Thus, specifying digital model contents has also become an important part of information exchange requirements in projects as project parties increasingly take advantages of these digital modeling capabilities.

Given the revolutionary, continuous, and diverse trends in identifying and generating information in projects, the industry has set forth the concept of "information integration" to develop project requirements that promote sharing of model information in project networks by consolidating information from different parties, technologies, tools, and processes (Kang et al., 2012). However, heterogenous groups of industry-leading organizations, professional associations, owners and clients in the construction supply chain have developed many different information exchange agendas across regions, market, and projects (Abdirad, 2015; Kassem et al., 2015). Consequently, in recent years, firms have faced an unprecedented variation of custom information exchange standards and requirements in their projects (Papadonikolaki, 2018).

With this overview of information integration agendas in practice, this research defines disruptive information exchange initiatives as custom project requirements that challenge routine processes, technologies, and media used for generating and exchanging design and construction information within and across firms. This definition is intentionally broad to account for the variability of routines in firms and that of information exchange initiatives in the industry (Poirier, Forgues, & Staub-French, 2017). Disruptive information exchange initiatives have attracted the interest of practitioners and researchers alike (Dainty, Leiringer, Fernie, & Harty, 2017). Research shows that firms often struggle to change their practice and adapt to such requirements (Çıdık, Boyd, & Thurairajah, 2017; Harty & Whyte, 2010). These requirements do not necessarily provide details of what each firm must do and how, but addressing them often necessitates new workflows and responsibilities that may conflict with existing practices (Çıdık et al., 2017; Jaradat, Whyte, & Luck, 2013). When enforced as parts of a new initiative, each firm may have a different understanding of these requirements (Jaradat et al., 2013). As a result of this uncertainty, the diffusion paths and outcomes of these initiatives are unpredictable (Harty & Whyte, 2010). Overall, the literature suggests that the attempts to address disruptive information requirements can result in "shifted" practices, whereby existing logics of practice are deconstructed and changed to make it feasible to adapt to initiatives (Çıdık et al., 2017; Kokkonen & Alin, 2016); or "hybrid" practices, whereby an amalgam or superimposition of existing and new practices emerges as existing logics are extended to accommodate initiatives (Harty & Whyte, 2010; Kokkonen & Alin, 2016). Despite offering important insights about the resulting organizational changes, prior research has fallen short of unpacking the mechanisms through which these requirements disrupt existing routines and the mechanisms through which firms respond to these requirements.

1-2-3- Organizational Routines: Definitions and Dynamics

1-2-3-1- Defining Organizational Routines

The importance of routines in organizations lies on the fact that a majority of what organizations do is performed through routines (Cyert & March, 1963; March & Simon, 1958) and they are a major source of productivity and reliability in organizations (March & Simon, 1958; Stinchcombe, 1990). Without routines, individuals will be overburdened with additional interactions, negotiations, and choices for doing their work. Routines provide relatively structured relations between individuals in addition to modularized capacities to perform the work. Therefore, routines are the necessary for avoiding full reflection over every detail and interaction in the work so the deliberative capacities can free up for more important issues (Hodgson, 2009).

The literature on organizational routines has offered three broad and relatively different interpretations of routines (van der Steen, 2009). The first interpretation suggests that routines are regularities in the collective patterns of behaviors or actions realized in organizational settings (Becker, 2004). The second interpretation conceptualizes routines as the formal rules and standard operating procedures that organizations have in their work (van der Steen, 2009). The third interpretation considers routines as dispositions, potentials, capacities, or capabilities for particular behaviors or actions. In contrast to the first interpretation of routines, routines can exist even if they are not observable, in-progress, or continuously triggered (Hodgson, 2009; van der Steen, 2009). Hodgson (2009) argued that routines store behavioral capacities or capabilities in an organization, thereby energizing conditional patterns of behavior in response to triggers or cues. He emphasized the necessity to make a distinction between the potential and the actual, between dispositions and outcomes, and between capacities and actual behaviors. In this perspective, the enduring and persistent quality of routine is not its alleged "predictability" or regularity of the behaviors or actions but it is the rule-like structure (formal or informal) that can be durable when the inputs and events that trigger routines are predictable (Hodgson, 2009). In other words, the predictability of routines does not stem from routines alone but also from the inputs, events, and conditions that trigger routines. Routines, as capacities or capabilities of an organization, involve knowledge and memory of triggers, individual habits, and sequential behaviors and actions. In contrast to the second interpretation of routines, the third view suggests that the knowledge and memory involved in routines cannot always be codified (like in standard operating procedures). In this research, the author uses the third interpretation and defines routine as the capacity to implement recurring patterns of interdependent behaviors and actions.

1-2-3-2- Stability and Dynamicity of Routines

There is a consensus in the literature that routines are context-dependent (historical, local, and relational embeddedness and specificity), path-dependent (they have history and change based on history), and repetitive (recurring), and recognizable patterns (or sequences) of actions carried out by multiple actors – humans or machines (Becker, 2004; Cohen & Bacdayan, 1994; Feldman, 2015; Feldman & Pentland, 2003; Pentland, Feldman, Becker, & Liu, 2012; Stene, 1940).

While the early theories of organizational routines emphasized the foregoing characteristics of routines to suggest their stability, recent empirical research clarified that routines can have internal dynamics that enable them to change (Feldman, 2000; Feldman & Pentland, 2003). Dynamicity and change in routines can be either adaptive or generative (Berente, Lyytinen, Yoo, & King, 2016; Feldman, 2015; Pentland & Feldman, 2005). Adaptive change refers to the ways in which organizations adjust their routines to adapt to changes that are exogenous to the routines. Generative change is endogenous as actors mindfully and gradually introduce change into their routines through reflective assessment, improvising performance, or deviating from existing routine aspects (Becker, 2004; Feldman, 2015). These adaptive or generative mechanisms of changing routines involve the internal interplay between the ostensive (general idea), performative (recurring performance), and artifacts (digital or physical objects) aspects of routines. As these routine aspects are mutually constitutive and interdependent, implementing or changing sociotechnical systems can be successful only when these elements mutually align (Volkoff, Strong, & Elmes, 2007). Accordingly, to understand stability, disruption, or change of information exchange routines, there is need to unpack and study the alignments or misalignments between ostensive, performative, and artifact aspects of routines as firms perceive and respond to custom information exchange requirements in projects.

1-3 - Research Gaps and Rationale

There are important limitations associated with the existing literature that studied the impact of disruptive project initiatives on information exchange routines in AEC firms. First, earlier research has examined such an impact on organizations only with a focus on project outcomes and resulting organizational changes (Harty & Whyte, 2010; Kokkonen & Alin, 2016). However, these episodic and static insights fall short of unpacking the mechanisms through which firms perceive, interpret, and act upon those information exchange initiatives that disrupt routines. Second, with a focus on isolated cases of information exchange initiatives, research to date has not yet addressed the unprecedented variation of information exchange requirements that a firm has to concurrently address across projects. Third, by approaching this topic with a project-network point of view (isolated or unrelated project networks), existing research has neglected whether and how different organizational constellations such as project portfolios and operations in a firm perceive and respond to the surge of project information exchange idiosyncrasies. Fourth, despite the importance of organizational routines for stability, change, and productivity in firms, little is known about the characteristics of information exchange routines in firms. To the best of author's knowledge, research in AEC domains has not yet adopted the theoretical lens of organizational routines in spite of its valuable conceptualizations of stability and change in organizations.

Many conventional studies of organizations, in fact, tend to see routines as black boxes that work with inputs and generate outputs (Pentland & Feldman, 2005). Although this approach can offer a general and simple perspective on the outcome or resulting changes in routines, it is unable to reveal the internal structure, potential variations, disruptions, and dynamicity of organizational routines. Unpacking organizational routines is, therefore, important to clarify how routines persist or change and how practitioners guide or prevent change in organizations (Pentland & Feldman, 2005). This research proceeds from the premise that AEC research has treated organizational routines as black boxes, without unpacking the ostensive, performative, and artifact aspects of routines. Therefore, information exchange requirements (as inputs) and organizational changes or other project outcomes (as outputs) have been the main concerns in prior research. Consequently, little is known about dynamics of perceiving and responding to disruptive information exchange initiatives. Accordingly, this research adopts a performative perspective on the study of disruptive information exchange requirements and their impact on organizational routines. The performative perspective considers that routines have dynamicity and variations and “are performed by specific people, for specific reasons, at specific times, in specific places” (Pentland & Feldman, 2005, p. 802). The performative perspective thus can compare potential variations or disruptions in performances of a routine with respect to changes in its context. This performative perspective is associated with the practice approach that aims to expose dynamics in the “logics of practice” (Feldman & Orlikowski, 2011).

1-4 - Research Goals and Objectives

The goal in this research is to facilitate improving the state of information integration and digital project delivery in the industry. Specifically, this research offers detailed insights on how the current trends in enforcing custom requirements undermine information exchange routines in firms, and how firms perceive and respond to those custom requirements that disrupt their routines. Therefore, besides its intellectual merits in advancing research and theories on this topic, this research aims to offer practical implications for (1) agencies, clients, and owners who develop and enforce information exchange standards in their projects, and (2) AEC firms who work with increasingly custom and diverse information exchange requirements in their projects.

1-5 - Overview of Research Approach and Questions

Consistent with the existing research on organizational routines, this research takes an interpretivist stance centered on the understanding of the thoughts, discourse, and actions that individuals attach to their experience (Mackay, Maples, & Reynolds, 2001). Interpretivism is a well-established approach to studying context-dependent and complex organizational phenomena (Saunders, Lewis, & Thornhill, 2009). This approach, therefore, facilitates “practice” research that explores how and why elements of practice evolve in certain ways (Feldman & Orlikowski, 2011;

Pettigrew, 1997). In-depth research into such complexities is often pursued through qualitative methods of inquiry and case-studies of natural organizational settings (Langley, 1999).

Accordingly, this research presents ethnographic case-studies of AEC firms over a period of time as they experience and respond to a variety of information exchange requirements. This study will use qualitative research methods since they are "well-suited for examining complex social structures, processes, and interactions that require consideration of numerous dimensions and levels of analysis," and "they are particularly valuable for unraveling the mechanisms underlying causal processes, especially those that occur over time" (Lamont & White, 2005, p. 10). Table 1 presents a summary of the research agenda, research questions informed by the foregoing review of the literature, and analytic methods chosen to probe the questions. The following sections present an overview of research methods applied in this study.

Table 1 – Research Agenda, Questions, and Analytic Methods

Research Agenda	Research Questions	Analytic Method
Exploration	What types of disruptions do firms experience in working with custom information exchange requirements?	Thematic Analysis (inductive)
Description	How do firms perceive, interpret, and act upon disruptive information exchange initiatives in a project? What reasoning mechanisms and knowledge processes do practitioners use to perceive and respond to disruptive information exchange initiatives in a project?	Grounded Theory (inductive)
Description Refinement and Theory Testing	How do firms perceive and respond to the surge of disparate information exchange initiatives in a multitude of projects? What response mechanisms do practitioners use to address the variations and incompatibilities of disruptive information exchange initiatives across projects?	Grounded Theory (inductive and deductive)

1-6 - Overview of Case Selection Criteria

This research pursued cases that enforced custom requirements aimed at the implementation of state-of-the-art information integration agendas in the construction industry. In identifying and selecting cases, the author noted that the disruptive impact of project requirements is not necessarily equal on different industry participants and project parties. Therefore, this study accounted for the variability of information exchange agendas and their impact on different project parties in all stages of research. These considerations enabled this research to make a timely empirical contribution to the studies of Construction Operation Information Exchange (COBie) and BIM Cloud Collaboration as two contemporary disruptive initiatives. COBie is a set of information exchange processes and artifacts that require project parties to incrementally collect, organize, and exchange spatial and equipment data generated within their scope of work for hand-over to asset owners. Therefore, the main goal of COBie is to minimize the redundant and independent data collection efforts that project parties, especially owners, have in their conventional practice of aggregating facilities data (East, 2013). COBie is more demanding, hence more disruptive, for builders than designers and engineers in terms of scope of data collection and constraints it puts on their conventional practice. Therefore, two of the case-studies presented in this dissertation focus on implementing COBie in a construction project.

BIM Cloud Collaboration is a commercial service coupled with conventional BIM tools to store, maintain, and share models on cloud servers for real-time collaboration on models. This service can exclude serialized model transmittals and fragmented information exchanges from project workflows, thereby enhancing information integration among project parties. Accordingly, cloud collaboration artifacts and processes can significantly impact design and engineering phases of projects, wherein project parties recurrently generate, revise, and exchange technical information. One of the case-studies presented in this dissertation explores the custom implementations of cloud collaboration in a large portfolio of projects in an engineering firm.

This selection of different information exchange agendas and cases allows for (1) improving the representativeness of findings and descriptions, and (2) reaching the appropriate level of abstraction to make broader claims about how this surge of custom information exchange requirements impact existing routines in firms, and how firms perceive and respond to this phenomenon as they strive for maintaining their information exchange routines.

1-7 - Research Methods

While the classic social science (hypothetico-deductive) requires establishing clear-cut definitions for categories (or constructs) and their properties before collecting data, categories and their properties in grounded theory are derived directly from data. The classic grounded theory approaches recommends that researchers delay reading and considering the existing theoretical literature in order to remain as open as possible to new discoveries and avoid forcing theories and concepts on data. Critics, however, argue that ignoring existing theories and research can lead to a loss of knowledge, risking reinventing the wheel, and repeating others' mistakes (Lapan, Quartaroli, & Riemer, 2011). Therefore, later developments in grounded theory suggest that the use of existing literature is appropriate as long as it does not block new discovery. In fact, having knowledge of existing literature can help researchers to (a) become more sensitive to subtleties in data, (b) consider alternative concepts and theories for making comparisons, (c) generate stimulating questions during data collection and analysis processes, and (d) improve their theoretical sampling to account for/rule out competing theories and explanations (Strauss & Corbin, 1998). Accordingly, this research adopts a grounded theory approach that employs the modern connotation of theoretical sensitivity, which is the ability to recognize relevant data and to reflect upon empirical data with the help of existing theoretical terms. Theoretical sensitivity in this context means that an empirically grounded theory critically combines categories and propositions that emerged from data with concepts from previous theoretical knowledge, although a strong commitment to specific preconceived theories should be avoided (Kelle, 2010). Accordingly, in the case-studies presented in this research, the author collected and analyzed qualitative data in light of the existing research to advance theoretical propositions (Lamont & White, 2005; Yin, 2003). For instance, to analyze how disruptive information exchange requirements influence routines in practice, the author considered potentially relevant theoretical threads in AEC literature and organization theory that addressed (a) disruptive forces that impact organizations (e.g. institutional and inter-organizational forces) and (b) different constellations of practice (e.g. projects, portfolios, operations, and firms).

This section summarizes the methods applied to systematically collect and analyze data in case-studies. The author applied field observation, informant interviews, and artifact analysis to triangulate different data collection methods, data sources, and data types (Given, 2008; Yin, 2003). For data analysis, following the qualitative traditions, the author (1) identified codes and themes, (2) developed and applied coding schema, (3) described phenomena through analytic memos (4) made comparisons across themes and categories in data, and (5) linked themes and categories into substantive and formal theoretical propositions, and (6) continuously checked the propositions against available data (Bernard, 2006; Lamont & White, 2005). Accordingly, the techniques applied in these processes included axial coding, memoing, constant comparison method, and time-ordered mapping of categories (Bernard, 2006; Ryan & Bernard, 2000; Strauss & Corbin, 1998).

To address the credibility of data (construct validity), the author applied triangulation of data sources (e.g. field notes, artifacts, interviews) and member-checking the findings with informants. To address the internal validity of theoretical models, the author considered multiple model-building techniques (axial coding, memoing, constant comparison, and time-ordered mapping). To address external validity of theoretical models, different mini cases in each case-study were explored to test propositions. Rather than a statistical generalization, the goal in the case-studies was to achieve a theoretical (or analytic) generalization, i.e. understanding what selected cases offer to the existing theories and understanding of the phenomenon (De Vaus, 2001). To address the reliability and replicability of the case-study research method, the author created detailed case-study protocols and reported all steps of data collection and data analysis in the following chapters (Strauss & Corbin, 1998; Yin, 2003).

1-8 - Outline of the Dissertation

The author presents this research in five chapters:

- Chapter 1 provided an overview of the research problem, gaps in existing research, research questions, and finally the rationale and methods used to design and explore the three case-studies presented in the subsequent chapters.
- Chapters 2 presents a case-study of implementing a custom COBie initiative in a project of a large public institution. By a comparative analysis of normative and descriptive models for implementing COBie in practice, the case-study identifies the types of disruptions that firms experience in working with custom information exchange requirements. Specifically, this case will show that assumptions that underpin the

COBie requirements conflicted with the conventional scope, sequence, and timeline of project workflows.

- Chapter 3 supplements the case-study presented in Chapter 2 with additional data and in-depth analysis to explore how project parties perceived, interpreted, and acted upon the disruptive impact of transfer-to-operation information exchange initiatives. The case-study contributes to research by unpacking the reasoning mechanisms and knowledge processes that practitioners used to perceive and respond to disruptive information exchange initiatives in the project.
- Chapter 4 presents a case-study of implementing custom BIM cloud collaboration protocols in a large portfolio of design projects in an engineering firm. This case validates and builds on the other case-studies by explaining how firms perceive and respond to the surge of disparate information exchange initiatives in a multitude of projects. Specifically, it contributes to this research by revealing the response mechanisms that practitioners used to address the variations and incompatibilities of disruptive information exchange initiatives across multiple projects. Furthermore, Chapter 4 spotlights the shifting loci of information integration in practice as custom initiatives increasingly pressure practitioners to shift the focus of their information integration from their more permanent practice at firms to temporary workflows in projects. By exploring a longitudinal case-study, Chapter 4 explains how AEC firms build routines around frequent disruptions.
- Chapter 5 reviews how the three case-studies, individually and collectively, contribute to research. It also outlines their implications for practice, limitations, and recommendations for future research.

Chapter 2 - Discrepancies and Limitations of Normative and Descriptive Models for COBie Implementation

2-1 - Chapter Summary

This study seeks to understand why the Construction Operation Building information exchange (COBie) standard, as an information integration initiative enforced by clients on project parties, has failed to become mainstream across the construction industry despite the significant attempts to promote it. This study builds this understanding by comparing the normative model of COBie outlined in the COBie documentation with a descriptive model of COBie developed through a case-study of COBie implementations. Whereas the normative model was based on the assumptions and planned procedures of the originators of this standard, the descriptive model was developed through a thematic data analysis of ethnographic observations, interviews, and artifacts. The comparative analysis of the normative and descriptive models showed that the underlying normative assumptions of COBie can be challenged in its implementation. In the case-study, implementing COBie disrupted the conventional practice of a few participating firms as the data requirements and the expected sequences and timelines of tasks were not aligned with the industry norms for exchanging data. Furthermore, the normative model of COBie did not account for the unanticipated variability in the internal routines of firms for submittal production. COBie, as an instruction-based model, did not provide enough flexibility for these firms to integrate it with their existing workflows. COBie tasks became additional efforts, and at times, conflicted with the industry norms and firms' routines, and therefore, disrupted the efficiency goals. This chapter is published as a case-study paper in the journal of Engineering, Construction, and Architectural Management (Abdirad & Dossick, 2019a).

2-2 - Introduction

The annual cost of inadequate data exchange in the U.S. capital facilities is on the order of billions of dollars due to the redundancies in data collection, re-entry, and validation in design, construction and operations of built assets (Gallaher et al., 2004). This issue has motivated the proliferation of information technologies and data exchange standards in the industry (Abdirad & Dossick, 2020). Construction Operation Building information exchange (COBie) is a prominent instance of these standards, which was devised to facilitate systematic collection and exchange of data needed for designing, building, and operating built assets (East, 2007). The U.S. Army Corps of Engineers developed and documented COBie through a series of industry advisory meetings. COBie standards and guidelines have been published since then, and it has become a part of the National BIM Standard in the U.S (National Institute of Building Sciences, 2015), the BSI in Britain (The British Standards Institution, 2014), and ISO standards (ISO, 2014). COBie addresses two important issues in asset management: (1) the loss of dispersed asset data during transitions from one project stage to another, and (2) the cost associated with data loss or data unavailability (e.g. inefficient asset maintenance). With COBie, project parties incrementally collect, organize, and exchange spatial and equipment data generated within their scope of work for handing-over to asset owners. Therefore, the main goal of COBie is to minimize the redundant and independent data collection efforts that project participants, especially owners, have in their conventional practice (East, 2013).

When COBie was first proposed to the industry in 2007, the question was why no one had fixed the problem of asset data exchange before then (East, 2013). Now, more than a decade after its development, today's questions concern why COBie has not fully become mainstream across the industry despite the significant attempts to promote it through the industry standards (Pärn, Edwards, & Sing, 2017). To answer these questions, this paper reports on a case-study to (1) develop a descriptive model of COBie implementation and (2) compare it to the normative model of COBie as documented in its guidelines. This comparison will highlight the discrepancies between the normative and descriptive models for COBie. This will also clarify why and how the normative assumptions of COBie are challenged in its implementation, and why the attempts to enforce this standard can be disruptive to project delivery. The findings of this study suggest that (1) COBie requirements can conflict with the industry norms for data development and exchange and (2) COBie procedures fail to account for the unanticipated variability in the internal routines of project parties. This evidence shows that COBie implementation is not necessarily a cost-saving workflow addition, especially when COBie tasks require additional efforts as opposed to being integrated into the existing practice of project teams.

2-3 - Literature Review

Since its development, COBie has received considerable attention in research and practice as it spotlighted the cost of redundant data collection in design, construction, and operations (East, 2007, 2013, 2016). Therefore, several governmental agencies (e.g. GSA, NASA, USACE in the U.S.) and institutional owners were persuaded to implement COBie. Many stakeholders attribute this progress to (1) the timing of proposing COBie to practice, which was aligned with the proliferation of information technologies (e.g. Building Information Modeling; Yalcinkaya & Singh, 2015), and (2) its promise to help facility owners save man-years of efforts spent on data collection for new facilities (East, 2013, 2016). However, the attempts to promote this standard, in many cases, led to what some scholars perceived as "unrealistic optimism" about the efficiency of its process and the value of its product (Yalcinkaya & Singh, 2015). Over the years, the literature recorded some criticism of COBie. For instance, some reports suggest that COBie implementation is fractured, loosely coordinated, and infrequent at the industry level (Maradza, Whyte, & Larsen Graeme, 2013), and the majority of owners in the U.S. and U.K. have not adopted COBie for these reasons (except when mandated by the governments; Bernstein & Jones, 2014; Eadie, Browne, Odeyinka, McKeown, & McNiff, 2013). Regarding its scope of data requirements, the critics argue that COBie does not satisfy all information requirements for asset management, and there is a technical limitation in customizing requirements in COBie data schema (Abdirad & Lin, 2015; Patacas, Dawood, Vukovic, & Kassem, 2015). Some evidence also suggests that limitations in current technologies inhibit effective COBie implementation (Maradza et al., 2013). Many project teams still question the efficiency of the recommended processes and technologies to populate and exchange COBie data (Cavka, Staub-French, & Poirier, 2017; Eadie et al., 2013). Furthermore, facility owners express reservations about the value of "a frozen" dataset detached from its data sources and delivered without potentially important tacit knowledge of assets (Lindkvist & Whyte, 2013).

In response to critics, some owners believe that implementing this evolving standard is better than not having any standards (Bernstein & Jones, 2014). Some reports argue that owners have not articulated COBie requirements effectively as a result of disregarding its customizability (National Institute of Building Sciences, 2015). Prior research also shows few cases in which owners themselves did not identify their data needs carefully and did not require COBie from all parties early in their contracts; consequently, the project teams did not deliver reliable COBie datasets (Lavy & Jawadekar, 2014). Despite all these observations, COBie developers suggest that COBie has been successful in terms of industry acceptance, considering that the pace of adopting new standards and technologies in the industry is generally slow (East, 2016).

Overall, despite the significant attempts to promote COBie, the literature suggests that this standard is not well-received among practitioners (Pärn et al., 2017). The literature, however, lacks sufficient details to enable stakeholders to manage their expectations of COBie or consider improvements that can be made to this standard or its customizations. This study takes a deeper look into COBie implementation, and it aims to provide empirical evidence on why implementing COBie has not been as straightforward for all industry players as expected. Specifically, the main goal is to offer some descriptive insights into the experience of project participants in implementing COBie to clarify what underlying normative assumptions of COBie can be challenged in conventional projects.

2-4 - Analytical Framework and Research Methods

In this paper, the author uses the concepts of normative and descriptive approaches to work analysis, which are two approaches to study socio-technical systems. Normative approaches pre-define how a system and its components should behave, whereas descriptive approaches describe how a system actually behaves (Rasmussen, 1997; Vicente, 1999). In this paper, the author reports the discrepancies between the normative and descriptive models for COBie. The author first introduces the concepts of normative models to clarify how the normative model of COBie was framed, and then presents the research methods used for developing a descriptive model for COBie.

2-4-1- Normative Approaches

In normative approaches, analysts often focus on expected behaviors and tasks that must be carried out in a system (Rasmussen, 1997; Vicente, 1999). This emphasis on what workers or technologies must do makes this approach a quest for identifying one best way of doing a job

(Vicente, 1999). In task analysis, three levels to identify and describe tasks can be considered. These include (1) inputs/outputs, (2) sequential flows for tasks, and (3) timeline of performing tasks. At the input-output level, in addition to system inputs and outputs (e.g. data, documents), the analysis should identify the constraints that influence them. The constraints may not specify a unique task, but they usually limit the potential options. At the sequential flow level, a temporally ordered sequence of tasks is identified. This level of task analysis may be dependent on the specific devices and tools used in a work since different devices may require different tasks or sequences. At the timeline level, which is the most detailed level, the time and duration of performing tasks are determined.

By identifying the constraints, the input-output level clarifies what should not be done (constraint-based). The sequential flow and timeline analyses specify the inputs and outputs as well as instructions for what should be done, the sequences, and timeline (instruction-based). Accordingly, task analysis in normative approaches can be categorized into constraint-based models (specifying inputs-outputs and constraints) and instruction-based models (specifying inputs-outputs, constraints, sequences, and timelines). The instruction-based models are more common; they provide detailed and pre-planned guidance, behavior, and rules, but leave less discretion to the workers (Rasmussen, 1997; Vicente, 1999). Therefore, it is less likely that workers forget a step, perform wrong steps, or perform steps in a wrong order. The constraint-based models determine the goals and the constraints, but they give workers some discretion to decide how to perform the work. Therefore, the constraint-based task analysis can lead to variability in the tasks, whereas instruction-based task analysis significantly limits the variability (often directing a single way to do the work). The instruction-based techniques are based upon certain assumptions about the state of the world. If the conditions change or are unknown and if a worker makes an error, the assumptions and the guidance based upon the assumptions become invalid. Consequently, instruction-based techniques have less flexibility for coping with changing circumstances (Vicente, 1999).

These implications of the instruction-based and constraint-based models can be explained by distinguishing between open and closed systems. Closed systems are isolated from their environment. The more closed a system is, the more amenable it is to instruction-based task analysis because the conditions are predictable and realistic assumptions can be made for designing systems. Conversely, open systems are subject to external (and often unpredictable) influences, and therefore, less amenable to instruction-based techniques (Bell, Raiffa, & Tversky, 1988; Vicente, 1999). Because of the unpredictable disturbances, open systems cannot accurately pre-identify the required tasks, sequences, and timelines. In open systems, workers must deal with unforeseen disturbances, and constraint-based techniques can partially provide some flexibility to the workers. In summary, normative approaches cannot always account for uncertainties, unanticipated events, and changes in requirements and goals (Bell et al., 1988; Vicente, 1999). They are also narrow in their generality because they are limited to the goals that have been identified up-front or to the particular ways, sequences, and timeline of doing the tasks (Vicente, 1999).

In this study, the author frames the normative model for COBie to conduct a comparative analysis against a descriptive model for COBie. The author analyzed the main published documentation for COBie (e.g. East, 2007, 2013; ISO, 2014; National Institute of Building Sciences, 2015; The British Standards Institution, 2014) and identified the underlying assumptions, constraints, sequences, and timelines for tasks. Accordingly, the normative model will clarify that COBie is an instruction-based standard, and therefore, its assumptions, sequences, and timelines can be challenged in construction projects (as open systems).

2-4-2- Descriptive Approaches

The problem with normative approaches is not necessarily that they prescribe tasks, sequences, and timeline in a system; the problem is the a-priori assumptions of the potentially unpredictable or changing conditions (Vicente, 1999). The behavior of workers in practice can deviate from the predicted ideals of normative approaches (Rasmussen, 1997; Suchman, 1987). The existing research suggests that, in open systems, workers do not, cannot, and even should not follow the detailed prescriptions of normative models (Rasmussen, 1997; Vicente, 1999). Therefore, descriptive approaches to work analysis aim to understand how workers actually behave in practice. This understanding of the practice then can be used for organizational learning, understanding dynamic environments, and suggesting new design ideas for systems (Rasmussen, 1997). However, this does not mean that an ideal system design must be based solely on descriptive models. Descriptive models by themselves may lack sufficient insights into unexplored possibilities. Therefore, the analysis of current tasks, technologies, and organizations is important but must not be considered as an end in itself (Vicente, 1999).

For the descriptive model, this research explored a descriptive case-study in its natural field setting (De Vaus, 2001; Yin, 2003), and it involved ethnographic study of a construction project and its participants over a period of time as they worked on a customized COBie specification. The case-study, hereinafter called the “Science Hall” was an active construction project of a higher-education institutional owner in the United States. This institution repeatedly procures new construction projects, and it has enforced custom COBie specifications in its construction projects since 2010. Science Hall was a 135,000 ft^2 facility with a variety of spaces such as instruction and collaboration rooms, library, auditorium, and research labs. The project team estimated to have approximately 500 major assets (mechanical, electrical, and plumbing), with 8000 data points, within the data collection scope. The unit of analysis in this research was the participating firms (e.g. the owner, owner representatives, general contractor, architect, engineers, subcontractors, consultants). This analysis of different firms was especially important for comparing their experience to the normative assumptions and to the experience of the other parties. The case selection was information-oriented (Flyvbjerg, 2006), i.e. it was perceived as particularly suitable for offering new perspectives on the types of disruption that project participant experience in working with COBie. Accordingly, the main case-selection criteria included (1) enforcing COBie or similar highly custom data delivery requirements, and (2) being a data intensive project that requires data exchange among multiple parties. This study used qualitative methods for data collection and analysis since they are "well-suited for examining complex social structures, processes, and interactions that require consideration of numerous dimensions and levels of analysis" . The author systematically collected data, with the goal of triangulating evidence across multiple data sources and data types (Lamont & White, 2005; Yin, 2003). The methods and procedures the author implemented for data collection are summarized in Table 2.

Table 2 – Data Collection Methods and Procedures

Data Collection Methods	Procedures
Ethnographic Observation	The author observed recurring project meetings for coordinating COBie data delivery (monthly) and commissioning (biweekly) during the construction stage (15 months). These observations focused on the interactions and communications among the contracting parties as they discussed (1) the requirements in the specifications, and (2) their workflows and progress in information development and exchange. The author collected data in different formats, including field notes, audio recordings of meetings, and artifacts (e.g. documents/spreadsheets). The data gathered in this process were used for (1) direct data analysis in the data analysis software (Atlas.ti), and (2) eliciting more information from informants in interviews.
Artifacts Analysis	The author analyzed the project specifications, information exchange media (e.g. drawings, data spreadsheets), and project communications relevant to the specification. This analysis facilitated identifying the project requirements, and it showed how project participants responded to these requirements in their communications, developments, and deliverables. Furthermore, these materials were used for eliciting information from informants in interviews for data triangulation.
Informant Interviews	The interview component enabled this research to obtain insights into organizational practices, contextual factors, and other project interactions that were not readily observable or identifiable in ethnographic observations or in artifacts due to the complexity of the project. This research used a semi-structured protocol for interviews. The interview protocol included the following components: (a) review of organizational settings in the project and in the firms involved in the implementation of the customized COBie specification, (b) questions regarding the informant's perspective on how the specification impacted their practice, (c) questions regarding the processes the informant's firm implemented to prepare the deliverables, and (d) questions regarding the variations they experienced across different projects in working on similar specifications. The author pilot-tested the interview tool with two individuals familiar with COBie implementation in the institution (an owner's agent, and a former general contracting project engineer). The focus of the pilot test was on language, clarity, neutrality, meaning to respondents, and order of questions. The author used snowball sampling to identify interviewees from different project participants who were involved in the work on the customized COBie specification. The interviewees included the owner's representatives (project manager, transition to operations agent, engineers, facilities manager), project managers and engineers of the general contractor (GC) and two subcontractors, and facilities management (FM) data consultant, with professional experience ranging from 4 to 26 years. The author conducted nine initial interviews and five follow-up interviews (a total of 14). The interviews lasted one hour on average. The interviews were digitally recorded, transcribed, and entered into a qualitative data analysis software (Atlas.ti) for data analysis.

This study applied a qualitative data analysis method that treated field notes, transcribed interviews, and artifacts as the proxies for experience (Ryan & Bernard, 2000). The author comparatively analyzed the normative model of COBie and the case-study data to identify codes and themes (Bernard, 2006; Lamont & White, 2005). For the normative model, the author focused on identifying assumptions and system analysis levels such as inputs, outputs, sequence, and timeline. The author then used the thematic analysis method to compare the themes that emerged from the analysis of the normative models to the themes that emerged in the case-study, with a focus on the discrepancies between the normative and descriptive models (Bernard, 2006; Lamont & White, 2005). The author then created narratives and analytic memos that explained the discrepancies. To address the validity of the data, triangulation of data sources (e.g. field notes, artifacts, interviews) and member-checking the findings with informants were used (participant validation). To address the reliability and replicability of the-case study, the author documented the detailed case-study protocols as reported in this section (Given, 2008; Strauss & Corbin, 1998; Yin, 2003). This study is limited to one case in the U.S. Thus, it does not offer a statistically generalizable claim or prediction regarding the feasibility and efficiency of COBie implementation in all projects. Rather than a statistical generalization, this paper offers an information-oriented case (Flyvbjerg, 2006) and achieves an analytic contribution (De Vaus, 2001), i.e. understanding how the selected case contributes to our understanding the disruptive impact of COBie on project parties, and by extension, they types of disruptions that custom information exchange initiatives impose on project.

2-5 - Framing a Normative Model for COBie

With conventional project submittals as data sources or inputs, COBie assumes that asset data are normally found on project submittals (e.g. drawings, reports, manuals). Accordingly, through the sequential stages of a facility life-cycle, project parties incrementally aggregate and organize asset data (East, 2013). Designers aggregate and deliver data on spatial attributes (facility, floors, spaces, zones) and scheduled equipment (systems, types, and components) that are normally found on drawings (Figure 1). In the construction stage, contractors add construction data (e.g. installation date, serial number) to the COBie dataset. At the project handover stage, contractors and commissioning agents add data on operations and maintenance requirements (e.g. warranties, parts) to the dataset. There are also common data requirements that all parties must populate during the project (e.g. contact info, documents) (East, 2013). The lead designer and the lead contractor must ensure that their downstream contracts (with consultants, subcontractors) specify relevant COBie requirements for in the deliverables (The British Standards Institution, 2014).

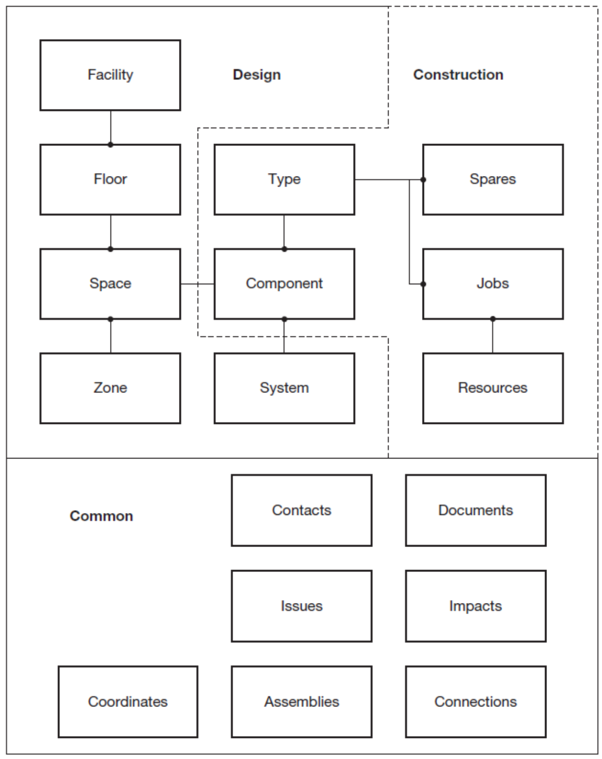

Figure 1 –Data categories specified in COBie

Each category requires some data attributes for the items that project participants identify (e.g. Installation Date for components, or Manufacturer for types) (East, 2013).

Regarding the sequences and timeline of implementation, COBie presumes a progressive data aggregation process. Also, there are several milestones in a facility life-cycle at which COBie datasets can be formally delivered: (1) after facility planning (as-planned), (2) after facility design and construction documentation (as-designed), (3) after facility commissioning (as-constructed), (4) when the facility managers take over the building for beneficial occupancy (as-occupied), (5) after the fiscal completion and construction contract close-out (as-built), and (6) during operations and maintenance (as maintained) (East, 2013). Most guidelines on COBie also recommend interim data submissions between these milestones. For instance, some guides recommend monthly data submission and check-ins for equipment-heavy facilities (East, 2013). These incremental and frequent data collection processes during the project life-cycle stages suggest that while certain data become fixed over time, some data may change and need revisions (National Institute of Building Sciences, 2015).

2-5-1- The Business Case and Normative Assumptions

The COBie guidelines propose that a progressively aggregated COBie dataset can eliminate data exchange inefficiencies in all project stages, from the feasibility analysis to the construction close-out stage. The conventional inefficiencies in these stages are related to the non-value-added tasks like validating, copying, handling, searching, reformatting, and recreating data (National Institute of Building Sciences, 2015). To evaluate the financial feasibility of COBie implementation, in three case-studies, the COBie developers estimated that its implementation could result in more than 95% savings on the cost of asset data management in projects. These estimates and the proposed models for implementing COBie are based on some normative assumptions about the workflows for data generation, collection, and handover (East, 2013; National Institute of Building Sciences, 2015). These normative assumptions are summarized and listed in Table 3. In the findings of this paper, the author discusses how these assumptions are being challenged in a COBie implementation case-study (summarized in Table 3).

Table 3 – Normative Assumptions Outlined in the COBie Standard and Guides

Normative Assumptions	Analysis Level	Case-Study Descriptive Findings
COBie data can be used during all project lifecycle stages and their processes. COBie is financially feasible in that it eliminates redundant data collection, exchange, and validation processes (National Institute of Building Sciences, 2015).	**System Goals**	There were previously routine practices and media for information exchange. It was unclear as to how a COBie dataset should align with some existing practices or change it to save costs. The owner intended to use the dataset only for transitioning from construction to operations and maintenance.
COBie requires data that can be found in typical design and construction contractual documents. Theoretically, this makes COBie defensible in terms of transaction costs by avoiding additional fees from designers and contractors for non-typical data (East, 2013).	**Inputs - Outputs**	On multiple occasions, the project team questioned (1) the meaning of the required data attributes, (2) the owner's need for the data, and (3) the source of data which were not normally in conventional project documents.
COBie data should be delivered by the party who is conventionally and contractually required to create that data (East, 2013). The lead designer and the lead contractor must ensure that their downstream contracts specify relevant COBie data in the deliverables (The British Standards Institution, 2014). However, the downstream contractual agreements regarding COBie data delivery processes, roles, and responsibilities are outside the scope of COBie (East, 2007).	**Constraints ***	Managing the downstream contracts added another layer of data management and data handling sequences for submitting, reviewing, and approving data by the general contractor before handing-over data to the owner. The challenges included (1) delays in reviewing subcontractor submittals, (2) different timelines for working with different subcontractors, (3) reworks, (4) and re-assigning data collection responsibilities due to delays.
The Industry Foundation Class (IFC) was selected for COBie implementation. Considering that IFC is intended for computer-computer data exchange, the COBie standard aimed to also provide a spreadsheet format for presenting data to users. This enabled the stakeholder with no computer programming skills to work with data through conventional software (East, 2013).	**Constraints**	The number and configuration of data repositories can impose constraints on COBie data collection, exchange, submittal processes. COBie itself can also escalate such issues when its data exchange requirements (e.g. timeline for recurring incremental data exchange, revision, and submission) are unaccounted for in overall project information management.
Collecting data as soon as they are generated in a project will simplify preparing the deliverables for final handover (East, 2007). For example, collecting the installation data at the installation, startup, or testing of the equipment needs little additional effort compared to a data collection walkthrough at the project completion stage. The advantage to this is that the project participants do not have to capture and possibly lose the information several times during the project (East, 2013).	**Sequences - Timeline**	COBie data was aggregated but was not relied upon during the project. This data was prone to reworks because of the transient nature of data and the inevitable project change orders. This was also disruptive to the routinized sequences and timelines that the project participants internally had for their conventional data collection processes and led to additional data collection efforts.
* These constraints on the source of inputs and outputs have implications for task sequences because of the sequential nature of design and construction tasks and sequential data exchange between multiple parties.		

2-6 - Findings: A Descriptive Model of FM Data Delivery

2-6-1- The Project Context and the Data Specification

The project owner adopted and customized COBie in 2010 and implemented it in its new construction projects. Based on the lessons learned from a few projects, which showed that full COBie was not well received among the project teams due to its complexity, the owner revised it in 2016 to have a narrower scope. In Science Hall, the owner implemented a customized COBie specification that was named "Facilities Management Data Specification" (FMDS). The owner excluded many of the standard COBie requirements from the FMDS to make data collection easier for the project participants and focus only on the value-adding data. The excluded requirements were spreadsheet formatting, multi-tab representation of data, and data for Job, Resource, Spare, Assembly, Impact, Coordinate, Issue, Zone, and System sections of the COBie standard (Figure 1). The data requirements in the FMDS are summarized in Table 4. Despite this reduction in the scope, the normative assumptions regarding inputs-outputs, constraints, sequence and timeline (Table 3) remained as the bases for customizing the new specification.

The project parties had to deliver the dataset in a spreadsheet format to represent the as-designed (for the designer) and as-built (for the contractor) status. Per FMDS, the project parties had to submit the reference documents such as drawings and O&M manuals with the dataset. Regarding the timeline for developing data, the project specification indicated that "the contractor shall provide equipment information throughout the project as the information becomes available and approved for use" (FMDS). Data from a submittal had to be available when the relevant submittal was ready and approved, and the installation data must be collected when equipment was installed. Accordingly, for each piece of equipment, the timeline for approving the submittals or installing the equipment did not necessarily match those of the other equipment. The final deliverable had to be submitted to the owner within two weeks of the substantial completion. The owner hired a FM data consultant to coordinate the implementation of the FMDS across the portfolio of projects in this institution. The consultant provided the project participants with a web-based tool that facilitated organizing, tracking, and verifying the data when uploaded into the tool. The project participants had monthly coordination meetings to discuss the FMDS and their progress.

Table 4 – Data Requirements and Responsibilities in the FMDS

Data Categories	Responsible Parties		Data Requirements
	By Designer	By Contractor	
Contact Information	✓	✓	Email, company name, website, phone number.
Space Information	✓		Room number, room name, floor number, ceiling height, associated floor plans.
Construction Start-Data	✓		Equipment name, equipment location, equipment description, asset group, parent equipment or component (e.g. panel), support locations.
Submittal Data		✓	Installer, manufacturer, model, approximate cost, expected life, warranty duration, associated approved submittal.
Installation Data		✓	Serial number, name-plate photo, equipment photo.
Close-Out Data		✓	Associated commissioning report, associated O&M document, associated warranty document.
Referenced Documents		✓	Associated electronic files.
Decommissioned Equipment		✓	Equipment removed from the facility (equipment name, location, and asset group).

2-6-2- Goal- State Disruptions

The normative model emphasizes that COBie can be used in different business processes during all project life-cycle stages to actualize the savings projected in the business case (National Institute of Building Sciences, 2015). In Science Hall, this assumption was not realized as the owner intended to use the dataset only for transitioning from construction to operations and maintenance, for which the standard projected significant savings. Accordingly, despite being developed during design and construction, the dataset was not expected to be used during design and construction to benefit project processes. Considering the business case outlined in the standard, the owner expected this approach to still save the conventional costs of data collection and exchange because the scope of the FMDS was much narrower than the COBie standard. However, the findings showed that the project participants worked on the FMDS in parallel and in addition to what they routinely did in their projects. For instance, the GC and subcontractors created a warranty log submittal, as they usually did for their other projects, and used this warranty log to fill in the FMDS warranty data.

> *"For tracking warranties, [the contractors] create a log based on the MasterFormat categories to list warranties. In the FMDS, a higher level of detail is required as it is not just about MasterFormat categories; one has to itemize every item and track warranties individually." (FM Data Consultant - Interview)*

Similarly, for associating documents and reports to equipment data, the team had to re-work, rename, and repackage submittals specifically for FMDS in addition to the submittal packaging they normally did for the project.

> *"I might need help [from the GC] for repackaging submittals […] if there is partial submittals, re-submittals getting approved, multiple submittals or final submittals packaged and put together, we need to repackage and rename them for […] linking documents to their relevant asset " (FM Data Consultant – FMDS Coordination Meeting)*

This shows that there were routine practices and media for developing, exchanging, and using information for conventional processes. It was unclear to the project parties as to how a FMDS dataset should align with existing practices or change it to save costs. In the project participants' perspective, the industry norms (or standard of care in legal terms) governed what was generally expected of them and other parties in terms of providing and using project information and information exchange media (e.g. a clear distinction between the general way of preparing warranty logs and submittal versus the FMDS expectation). In the submittal production process, multiple information media like drawings, project reports, logs, and their different combinations were being used. FMDS, by itself, did not change or improve the practice of developing and working with the information needed in those processes. In summary, the FMDS targeted only submittal production and handover among the many business processes, and its implementation led to some rework and inefficiencies in production even in this narrow scope.

Beside the general norms for developing and exchanging project information, to satisfy and align with these norms, each firm had internal routines for preparing and working with data and submittals. The findings, as explained in more details in the following sections, suggest that another layer of disruptions in data delivery emerged when the requirements of the new specification (scope for inputs-outputs, sequences, timelines) imposed additional burden to the internal routines of the firms.

2-6-3- Inputs and Outputs

The assumption that COBie data are found on typical design and construction documents was challenged in Science Hall. On multiple occasions, the project parties questioned (1) the meaning of the required data attributes, (2) the owner’s need for the data, and (3) the source of data. For instance, for the data attribute “Expected Life,” the conventional design, construction, and handover documents (e.g. drawings, equipment catalogs) do not normally report the expected life of equipment. The GC and subcontractors questioned whether the owner expected the data based on the project participants’ judgments, industry standards, manufacturers’ knowledge of the equipment’s expected life or other sources (also expected life could vary based on equipment usage and maintenance regimes). Although the owner asked the project parties to use their judgment for estimating the expected life of equipment, the effectiveness of the data collection and verification tasks was deemed questionable due to the uncertainties in the sources of exchanged data and in the project participants' perception of the requirements. Similarly, for some of the other data attributes, the team questioned the required level of detail, breakdown, and accuracy (e.g. for "approximate cost") or granularity of data (e.g. for "commissioning report", "O&M document", "warranty document", and "electronic files"; whether larger documents should be broken down per each equipment or per categories of equipment). In summary, the assumption regarding the input and output of the system was challenged when the project participants were (1) unclear about the source or meaning of some data that were not normally found on project submittals, and (2) uncertain about the reliability of the inputs - outputs when the requirements were not clear or in accord with the industry norms.

2-6-4- Project Specification Constraints and Conflicts

The normative model assumes that COBie requirements are aligned with the data that project participants conventionally create and hand-over (East, 2013). Normatively, this could be interpreted as if adding the COBie specification to the conventional project specifications would not significantly change the requirements or require additional work. In Science Hall, this assumption was challenged such that the FMDS significantly influenced the relationships among the different specifications in the project. The GC found that the FMDS and four other specifications (Commissioning, Electronic Operation and Maintenance or e-O&M, Submittals, and Training) had interdependencies that could impact the data collection and handover process.

"we have a lot of questions as far as the different specs or overlaps, and we want discuss

these different specs and make sure we are finding here most efficient means of preparing submittals" (GC Project Manager –FMDS Coordination Meeting)

"there are some overlapping requirement that lead to inefficiencies that we are trying to eliminate; we are trying to clean it up, trim it down a bit, get rid of anything overlapping from one spec to the other" (GC Project Engineer – Interview)

For instance, the FMDS required a document name for each piece of equipment (e.g. name for O&M manual), but the requirements for naming the documents and submitting them were specified in the e-O&M specification. These data requirements imposed additional input-output constraints on the work on the FMDS. As another instance, the Commissioning specification required delivering some equipment data similar to the FMDS requirements (e.g. warranty and installation data) while the milestones for submitting the data for these specifications were not necessarily aligned. While some of these interdependencies and overlaps in the requirements were 'overt' and pointed out in the specifications, some of them were covert and brought to the surface only when the GC started to work on the requirements. These interdependencies influenced the efficiency of the data collection process because the timeline for working on different specifications varied (e.g. the FMDS was continuous during design and construction, while Commissioning activities began near the end of construction; Figure 2). Consequently, the overlapping or conflicting requirements on occasions led to rework on some of the requirements (e.g. renaming and repackaging documents multiple times, updating data due to revisions and changes). These findings showed that COBie must be treated as an open system as it influences and is influenced by some environmental phenomena such as interdependent specifications or overlapping requirements. This interaction with the environment can impose additional constraints on COBie deliverables (e.g. addressing naming conventions for data on reference documents) or implicitly demand alternative timelines for working on the requirements of different specifications to avoid rework (e.g. collecting document names and warranty data at different timelines).

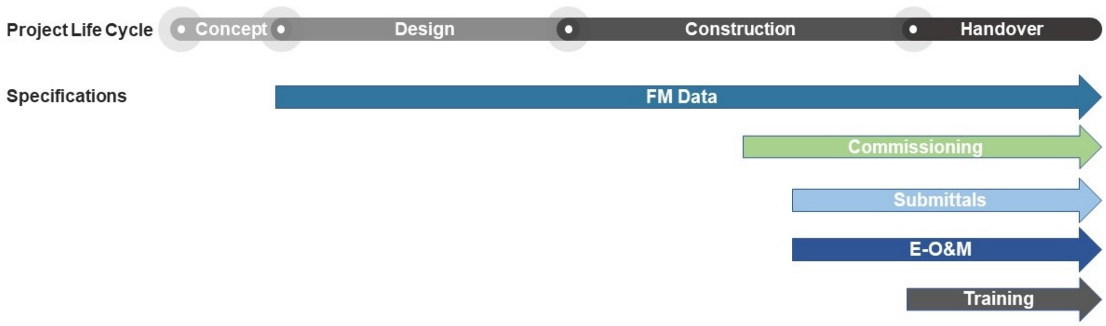

Figure 2 – The expected timeline for working on interdependent specifications.

In Science Hall, there were technical constraints that influenced the efficiency of the data collection and exchange processes. Each party used a spreadsheet file to populate data and sent it to the FM data consultant, who merged the spreadsheet files and uploaded the data to an online data repository dedicated for FMDS data. This repository was designed by the consultant to track the data collection progress and maintain the data. While the team did not face any issue in using and exchanging the spreadsheet files, they faced challenges in managing and working with more than several data and document repositories that they used during the project.

> *"We have multiple places where we are trying to put data and documents for all these different things, and it gets confusing, we want to have just a couple of places for […] everybody to find all they need." (GC Project Manager – FMDS Coordination Meeting)*

The project owner required working with separate repositories with different uses listed as follows: (1) a repository for exchanging general project submittals during the project (e.g. drawings) (2) a repository for uploading and handing over the as built drawings and O&M manuals, and (3) a repository for maintaining and tracking the FMDS data. The lead designer and

GC also had their own repositories that they used across their different projects with access given to the subconsultants and subcontractors to upload their submittals. The subcontractors also had their own document and data repositories for their internal workflows. The separated and decentralized repositories led to connectivity, access, and control issues because not all project parties could access all the repositories at the beginning, although they needed to access different documentation for populating relevant data (e.g. the FM data consultant did not have access to the owner's document repositories until midway in construction; Figure 3). Furthermore, data management across the repositories was asynchronous and project parties had to process and update project files manually across these repositories. While the COBie standard does not prescribe where and how the dataset or files must be stored and accessed during a project, the Science Hall project showed that the number and configuration of data repositories can impose constraints on data collection and exchange. Although the issue of having multiple decentralized repositories may be a broader issue than COBie, this study found that COBie is susceptible to such unpredictable disturbances in the project environment. Furthermore, COBie itself can also escalate such issues when its data exchange requirements (e.g. timeline for recurring incremental data exchange, revision, and submission) are unaccounted for in overall project data management.

Figure 3 – The Network of Data Repositories and Access Needed by Project Parties (each party owns and manages a repository and the arrows show the direction of requests for access to other repositories).

2-6-5- Sequence and Timeline Disruptions

The normative model suggests that downstream contracts of subconsultants and subcontractors (their roles and responsibilities) are outside the scope of the COBie standard. However, the constraint is that the lead designer and lead contractor must ensure that their downstream contracts specify COBie (East, 2007). Normatively, the leading parties can pass down the specifications for data delivery to other parties. In practice, however, managing downstream data collection processes can be quite challenging. In Science Hall, the electrical and mechanical subcontractors were actively involved in data collection. The GC collected data for equipment or assets that were not in the scope of work for these two subcontractors but were required in the FMDS. The involvement of the subcontractors in the data collection process was essential for Science Hall because these parties had a first-hand access to the equipment and relevant data. However, the GC faced some challenges in managing the team. First, the subcontractors had internal routines and timelines for collecting equipment data, which they implemented across multiple projects. Since these routines were specific and internal to these firms, they were not completely aligned with the requirements of the FMDS in terms of data collection sequences and timelines. For example, the mechanical subcontractor had a start-up specialty team that collected equipment data near the end of all projects, while FMDS required incremental data collection during the project when the start-up team was not involved. Second, the subcontractors collected and reported equipment data only when the GC had approved the relevant submittals (e.g. inspections, tests, drawings, reports) to ensure that they did not need to revise and re-collect data if the submittals were not approved. The GC's schedule for reviewing and approving the submittals was not always aligned with the data collection schedule, and at times, the GC had different schedules for reviewing the submittals of different subcontractors. Therefore, the speed of collecting and reporting data were not completely aligned for different parties in this process. Due to these uncertainties in the timelines for approving submittals and potential delays, after some discussions among the project participants the GC itself decided to collect some data that were originally requested from the subcontractors. For example, for naming the reference documents (per the interdependent e-O&M spec) the GC decided to populate the names and upload the data and documents for all submittals to ensure consistency and avoid delays and reworks on interdependent specifications. As the COBie guidelines suggest that the downstream subcontracts must require a COBie deliverable, but the details of roles and responsibilities are outside the scope of COBie, the question remained for the project participants as to what the best practice could be for efficiently managing the subcontractors' scope of work, sequences, and timeline of data exchange. This was especially important because managing the subcontractors' work on the FMDS added another layer of data management for submitting, reviewing, and approving data by the GC before handing-over data to the owner.

The COBie standard and guidelines advocate collecting data as soon as they are generated in a project. The guides suggest that this approach needs little additional effort compared to a data collection walkthrough near the end of projects, and project participants can use data during the projects. In Science Hall, despite collecting the FMDS data incrementally during design and construction, the project participants did not intend to use the data during the project because the only goal for the FMDS was to hand-over equipment data to the owner. Although the owner and the FM data consultant believed collecting data as soon as possible (e.g. when submittals were approved, when the equipment arrived at the jobsite, or when they were installed) could simplify the data collection process because of the easier access to the equipment, some project participants questioned the value of this approach for multiple reasons. First, the project participants had to collect and submit data each month, although the data was not needed, used, or relied upon before the end of the project. The project participants believed that they should have had the flexibility to plan for data collection themselves during the project to manage their data collection costs more effectively. Second, data aggregated during a project can have a transient nature, i.e. not finalized and likely to change and re-occur, because of the changes during design and construction or other unpredictable events (e.g. equipment failure during tests). In Science Hall, there were a few major changes made to the project during construction (e.g. adding wet-labs and a cafe with changes to the previously scheduled equipment) which led to removing or updating parts of the existing data. Due to the transient nature of data and the fact that the data was not relied upon during the project, the project participants believed that one push for data collection near the end design or construction would have helped them avoid re-collecting and updating the transient data (Figure 4). Third, for some parties, the additional effort required for incremental and early data collection was significantly more than what the COBie guides suggested. As stated earlier, the mechanical sub-contractor already had the established routine of collecting data near the end of projects, conducted by its start-up team. The incremental data collection during the project was redundant and imposed additional costs to the subcontractor because they could not change their routines in the start-up processes, which had a broader data collection scope than the FMDS and were implemented across their projects for different clients as a part of their general standard of care.

> *"We already have something dedicated, when startup starts, that can take care of all that information gathering and we will not be asking them to perform additional work, they will pick up the information at that time* ***[...]*** *you could have me to run around and grab all those but it is going to be duplicate effort […] out of routine" (Mech Sub– FMDS Coordination Meeting)*

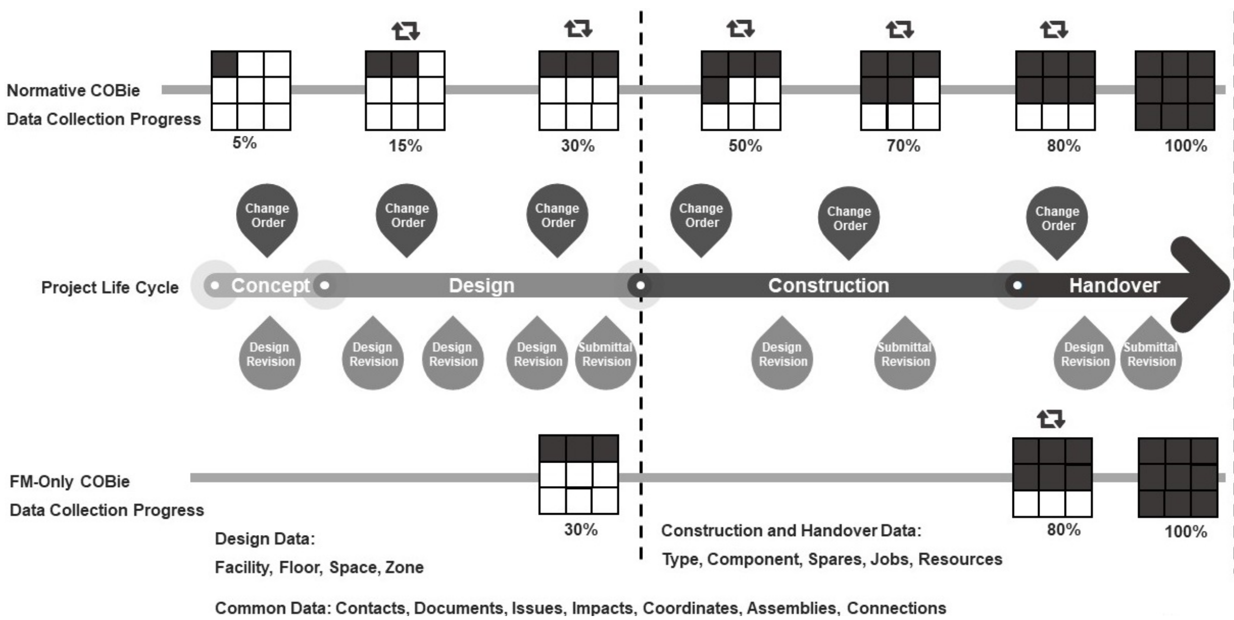

Figure 4 –Normative COBie data collection vs. FM-only data collection for flexibility in planning and avoiding changes to transient data (project participants' perspective).

In summary, the analysis in this section showed that the normative model of COBie recommends and implies a sequence and timeline for collecting and using data. When COBie data is aggregated but is not relied upon during the project, the recurring data collection tasks are perceived as reworks because of the transient nature of COBie data and inevitable project changes. Furthermore, this approach can be disruptive to the routinized sequence and timelines that the project participants internally have for their data collection processes. This can also lead to rework when the project participants cannot change their internal routines and workflows but must meet the sequence and timeline requirements. This is another illustrative example that shows COBie, as an open system, is susceptible to disturbances and unable to account for the internal routines of all parties for data collection sequences and timelines.

2-7 - Discussion and Conclusion

This paper reported on a case-study that highlighted the discrepancies between the normative and descriptive models for COBie. The findings showed that the normative assumptions of COBie were challenged in its implementation. This illustrative case demonstrated that the attempts to enforce even a narrower customization of this standard can be disruptive to the conventional practice. The COBie standard not only outlines the requirements (e.g. data inputs and outputs) and constraints for data collection (e.g. responsibilities), but it also guides the sequences of tasks and timelines for developing data. COBie, as an open system, influences and is influenced by the conventional practice of creating, accessing, exchanging, and working with project data and submittals. The evidence from this study suggests that the disruptions emerged because the data requirements, sequences of tasks, and timelines, as instructed by COBie, were not aligned with the industry norms (e.g. the conventional data or media that practitioners delivered in projects) and could not account for the variability in the internal routines of the project participants (e.g. allocating resources for data collection, timeline of routinized data collection).

Previous research highlighted that many information exchange standards in the industry aim to direct their stakeholders to a monolithic normative model while this approach can inhibit innovation, experimentation, and flexibility (Abdirad, 2015; Koch & Beemsterboer, 2017; Miettinen & Paavola, 2014). Accordingly, this paper provided empirical evidence that shows, in its current form, COBie is an instruction-based normative approach that can conflict with design and construction routines and industry norms because of its highly prescriptive scope, task sequences, and timelines. The implication of these results for practice is that COBie or similar data delivery standards must be customized with careful consideration of the local industry norms and its exposure to the project contextual factors. The author further posits that COBie guidelines should move toward a constraint-based approach to allow for adaptability into existing norms, practices, and multiplicity of routines of the industry participants. The projects into which COBie is interjected are open systems, where design, procurement, construction, commissioning, start-up, and handover have general norms (at the industry level) as well as unforeseen variability in the internal routines (at the firm level). COBie, when interpreted and implemented normatively, does not provide enough flexibility for workers to adapt to its requirements such that they become integrated with the existing practice or effectively improve them. Therefore, COBie tasks become additional efforts that are at times in conflict with the existing norms or routines. This issue can challenge the efficiency goals of facility owners in their implementation of COBie.

Being limited to one case-study, this paper does not offer a statistically generalizable claim regarding the feasibility, efficiency, and challenges of COBie implementation in all projects. Descriptive models by themselves also lack sufficient insights into unexplored possibilities. Despite these limitations, the empirical findings of this study offer some illustrative examples and insights into why COBie implementation can be disruptive to the conventional practice. Further research should explore the variations in customizing and specifying COBie (its constraints, tasks, sequences, and timelines) to analyze whether any changes to the original model or a transition from an instruction-based model to a constraint-based model can mitigate its disruptive impact. The idea of developing formative models (Vicente, 1999), in which project participants themselves finish the design of a system like COBie and find local alternative solutions (for constraints, sequences, and timelines), is an intriguing one which could be explored in further research.

Chapter 3 - Disrupted Information Exchange Routines in Construction Projects: Perception and Response Patterns

3-1 - Chapter Summary

The current proliferation of custom information exchange initiatives in projects disrupts the information exchange routines of design and construction firms. This paper investigates how firms perceive, interpret, and act upon information exchange requirements that do not align with their existing routines. This case-study examines a construction project for which the owner specified highly custom requirements for digital production and delivery of project submittals. Using ethnographic methods, the project parties' existing routines and their patterns of perceiving and responding to the requirements were identified. These patterns showed that the parties perceived disruptions to the existing dispositions and rules that guided their routines and shaped their performance across projects. The project parties used a combination of deductive, inductive, and abductive reasoning mechanisms to interpret the requirements, expose the inefficiencies associated with their workflows, and set new ground rules for action. The grounded propositions in this study hold that the limited opportunities for inductive reasoning and reflective assessment of workflows in projects can press project parties into identifying alternative workflows through cognitive search and abductive reasoning. This, in turn, results in highly situated, temporary, and fragmented workflows that are not durable and effective to contribute to refinement of existing information exchange routines. This chapter is published as a research paper in the journal of Building Research and Information (Abdirad, Dossick, Johnson, & Migliaccio, 2020).

3-2 - Introduction

In the architecture, engineering, and construction (AEC) industry, the large volume of information that project parties generate across organizational divisions poses a significant challenge to exchanging information (Zhou et al., 2016). Although the industry is characterized by its unique one-off projects (Stinchcombe, 1990), firms as business units have attempted to establish internal and external regularities for their information exchange (Harty, 2008). These information exchange regularities govern how firms create and exchange information media, use information technologies, and adapt to institutional norms for information exchange (Harty, 2005; Harty & Whyte, 2010). As such, these regularities can be studied as organizational routines, because they have recurring patterns of interdependent actions, involving multiple actors, to reinforce consistency and productivity within and across organizations (Becker, 2004; Feldman, 2015). Despite the importance of these routines for productive communication, firms increasingly struggle to maintain these routines because of the current proliferation of disruptive information exchange initiatives in the industry (Kalin et al., 2011).

This paper defines disruptive information exchange initiatives as custom project requirements that undermine routine processes, technologies, and media used for generating and exchanging design and construction information within and across firms. This definition is intentionally broad to account for the variability of routines in firms and that of information exchange initiatives in the industry (Poirier et al., 2017). With recent advancements in information modeling and digital production, firms have faced the proliferation of information exchange guidelines, protocols, mandates, and custom requirements across projects (Abdirad & Dossick, 2020; Kassem et al., 2015). While advocates for such initiatives see them as innovative solutions for poor communication (Eastman, Jeong, Sacks, & Kaner, 2010), attempts to adopt and adapt to them often result in resistance and disrupted practices due to their misalignment with existing routines (Harty, 2005; Harty & Whyte, 2010).

Disruptive information exchange initiatives have attracted the interest of practitioners and researchers alike (Dainty et al., 2017). Focused through the lens of organizational change and innovation diffusion, much of this research has studied how organizations transform their information exchange routines as they adapt to such initiatives (e.g. Çıdık et al., 2017). For instance, research has documented the emergence of hybrid practices (Harty & Whyte, 2010), incremental shifts (Çıdık et al., 2017), and reflective learning processes (Kokkonen & Alin, 2016) in firms as they change their information exchange routines. However, due to its focus on organizational outcomes and long-term adaptations (Whyte & Hartmann, 2017), the literature lacks empirical evidence of how project parties perceive, interpret, and act upon custom information exchange requirements that disrupt their routines.

This paper addresses this research gap using data from a longitudinal exploratory case-study of a construction project. The owner on this project specified highly custom requirements for documentation and digital delivery of project data and submittals. In line with extant literature (e.g. Çıdık et al., 2017), this study applied a "practice" approach to expose the "logics of practice" for addressing such requirements (Abdirad & Dossick, 2019b; Feldman & Orlikowski, 2011). The key contribution of this paper is that it empirically conceptualizes the underlying reasoning mechanisms that shape the perceptions, interpretations, and actions of project parties with respect to disruptive project information exchange requirements. Through this contribution, this study cautions research and practice to address the ongoing transition of information exchange practices from routine workflows to temporary, emerging, and fragmented solutions that undermine productive capacities within and across organizations.

3-3 - Background

3-3-1- Proliferation of Information Exchange Initiatives in the Industry

The evolution of design and construction practices in the past century led to a growing number of specialty businesses that participate on projects through subcontracts. This trend magnified the complexity of projects because it increased the business interdependencies and need for coordination among project parties (Dubois & Gadde, 2002a). Although the one-off, unique, and temporary nature of construction projects demands tight project-level coupling to address their specificities, relational stability between firms is often weak from one project to another (Dubois & Gadde, 2002a; Taylor & Levitt, 2007). The weak couplings at the firm level persist because (1) each project often involves a new combination of firms and (2) requirements for one project may not apply to other projects (Dubois & Gadde, 2002a). Therefore, each firm concurrently works on multiple projects and experiences variations in project requirements across their portfolios (Stinchcombe, 1990).

Despite the variations in project requirements, firms strive to regularize their practices to enhance project productivity (Bresnen et al., 2005). They also use established industry-wide adaptation mechanisms to institute behavioral and process norms (Dubois & Gadde, 2002a). Previous research suggests that information exchange is an area in which firms establish internal regularities in tandem with these industry norms. In fact, the processes, media, and technologies used for information production and exchange are embedded into these internal regularities, playing a significant role in establishing and changing them (Harty, 2005; Harty & Whyte, 2010). At issue here is the proliferation of fragmented and varied information exchange initiatives that disrupt these information exchange regularities.

In the past few decades, two important trends have led to the proliferation of disruptive information exchange initiatives: (1) innovations in construction means, methods, and products; and (2) advances in digital production and information technologies like computer-aided design (CAD) and building information modeling (BIM). These developments have had the effect of making projects more complicated and challenging, particularly in terms of information exchange.

With the evolution of construction means, method, and products, project specifications and submittals similarly evolved in their complexity. This increased complexity generated a "mild chaos" whenever practitioners used different methods to identify and organize information (Kalin et al., 2011, p. 14). This issue highlighted the need for standards that align the information required in submittals, for streamlined information processing and exchange. Since the 1960s, the efforts to develop these standards have exposed many inconsistencies in the methods of organizing and specifying project information; they have also led to the proliferation of ontologies and classification systems (Kalin et al., 2011). Prior research shows that these efforts have not been as effective as their developers intended because they lacked universally acceptable standards and had a fragmented focus on certain project types or information perspectives (Zhou et al., 2016).

With the more recent evolution of digital tools and information technologies (e.g., CAD and BIM), regulating information exchange for project submittals became even more challenging. This deeper challenge has arisen because digital production of building information additionally requires the alignment of digital organization, formatting, storage, and exchange of information across project parties (National Institute of Building Sciences, 2007). Due to the inconsistent and fragmented implementation of these technologies throughout the industry, owners now commonly develop custom information exchange requirements for projects (Abdirad, 2015; Kassem et al., 2015; Whyte & Hartmann, 2017). This customization adds to the variability of the disruptive information exchange initiatives in construction projects.

In sum, the tandem evolution of project execution capabilities and building information technologies has generated a growing stream of developing, changing, and customizing information exchange requirements in the industry (Abdirad & Dossick, 2019b). Indeed, firms now face an often overwhelming proliferation of standards and an urgent need to adapt to increased custom requirements across projects (Charef et al., 2019; Eastman et al., 2010; Zhou et al., 2016).

3-3-2- Existing Practices Adapting to Information Exchange Initiatives

Previous research has recognized communication and information exchange as potential risk areas in projects (Zavadskas, Turskis, & Tamošaitienė, 2010). The reason is the complexity of technological, organizational, and human factors that influence technical information exchange (Boujaoudeh Khoury, 2019). The following review of the literature shows that, given the complexity of these factors and variability of information exchange initiatives, it is often unpredictable how these initiatives affect organizations (Pala, Edum-Fotwe, Ruikar, Peters, & Doughty, 2016). Therefore, the conventional risk management approaches that aim to identify probability of risks, potential consequences, and magnitude of impact (e.g. Ceric, 2014; Goh, Abdul-Rahman, & Abdul Samad, 2012) may not be suited to effectively address these initiatives.

The literature suggests that firms often struggle to change their existing practices and adapt to information exchange requirements (Çıdık et al., 2017; Dainty et al., 2017; Harty & Whyte, 2010). These requirements do not necessarily provide details of what each firm must do and how (Çıdık et al., 2017). When enforced as part of a new initiative, each firm may have a different understanding of these requirements (Jaradat et al., 2013). Furthermore, the challenge is to determine whether these requirements are “bounded” and influencing only a single firm, or "unbounded" and spilling over the organizational boundaries of firms (Harty, 2005, 2008). As a result of this uncertainty, the diffusion paths and outcomes of these initiatives are unpredictable and generate a multitude of ways to adopt them (Harty & Whyte, 2010; Whyte & Hartmann, 2017). Also, these requirements also often necessitate new workflows and responsibilities that may conflict with existing practices (Çıdık et al., 2017; Jaradat et al., 2013). Overall, the literature suggests that the attempts to adopt and adapt to these requirements can result in the following kind of new practices:

a) “shifted” practices, whereby existing practices and logics are deconstructed and changed to make it feasible to adapt to initiatives (Çıdık et al., 2017; Kokkonen & Alin, 2016); or
b) “hybrid” practices, whereby an amalgam or superimposition of existing and new practices emerges as existing logics are extended to accommodate initiatives (Harty & Whyte, 2010; Kokkonen & Alin, 2016).

These insights from the literature shows how disruptive information exchange initiatives have been on firms (Çıdık et al., 2017; Kokkonen & Alin, 2016; Papadonikolaki, 2018). However, due to its focus on project outcomes and on resulting organizational changes (Papadonikolaki, 2018; Whyte & Hartmann, 2017), the research has fallen short of illuminating how project parties perceive, interpret, and act upon disruptive information exchange initiatives. Specifically, the reasoning mechanisms and knowledge processes that underpin project parties’ responses to disruptive information exchange initiatives are in something of a black box. This gap in the literature raises some pertinent questions: How do project parties plan and reason about their responses to disruptive initiatives? How durable or temporary are their responses? How and on what basis do these responses follow (or deviate from) existing practices? The emphasis the foregoing insights place on the role of existing practices in adopting information exchange initiatives highlights the opportunity to address these questions through the theoretical lens of organizational routine dynamics.

3-4 - Theoretical Lens: Organizational Routine Dynamics

This research proceeds from the premise that firms establish internal information exchange regularities (intra-organizational) and adapt to external information exchange norms across firms (inter-organizational) (Dubois & Gadde, 2002a; Harty, 2008; Harty & Whyte, 2010). Given these baseline regularities and norms, the theory of routine dynamics is the proper lens through which to unpack their underlying elements (e.g., knowledge, dispositions, processes, and artifacts) to understand how custom project initiatives may disrupt them.

3-4-1- Organizational Routines: Theoretical Foundations

In addition to being context- and path-dependent, organizational routines are repetitive patterns of interdependent actions carried out by multiple actors (Becker, 2004; Feldman, 2015). The importance of routines lies in the fact that a majority of what organizations do is performed through routines (March & Simon, 1958). Routines are a major source of productivity because they provide relatively structured relations between individuals and their interconnected work (March & Simon, 1958; Stinchcombe, 1990). Without routines, individuals would be overburdened with additional interactions and coordination in their work. Thus, routines are necessary for preventing time-consuming reflection over every detail of a process and for freeing-up resources for important organizational issues (Hodgson, 2009).

Organizations retain knowledge of routines as dispositions, capacities, or capabilities for action. Therefore, routines can exist even if they are not already in-progress (van der Steen, 2009). The salient feature of routines is not the supposed predictability of the actions they comprise; rather, it is the rule-like mechanism that can endure when predictable inputs and events trigger them (Hodgson, 2009). This is to say, the predictability of routines does not stem from routine actions alone, but also from inputs, events, and conditions that trigger routines. Accordingly, engaging in routines involves reasoning and learning about existing knowledge of these triggers, actions, and their outcomes (Bresnen et al., 2005; Hodgson, 2009). Drawing on these insights, through the case-study, this paper frames the deductive reasoning mechanism (Gabbay & Kruse, 2000; Reiss, 2011), through which project parties used and articulated their existing knowledge and dispositions of routines to verify the intent and question the feasibility of implementing custom information exchange initiatives.

3-4-2- Routine Dynamics and Reflective Assessment

While the early theories of routines emphasized their stability, theories of routine dynamics demonstrate that routines have internal dynamics that enable them to change continuously and endogenously (Feldman & Pentland, 2003). In these theories, routines are examined from two perspectives: the ostensive and the performative. Looked at ostensively, the stability of routines is attributed to general patterns and abstract ideas of routines. From a performative point of view, the dynamicity of routines is attributed to their actual performance (Pentland & Feldman, 2005). The ostensive aspect of routines reflects their durable disposition, i.e. the repeatability that people rely on to guide, account for, and refer to their performance; while the performative aspect is important for creating, maintaining, and changing the ostensive aspect through practice (Feldman & Pentland, 2003). This mutual relationship between the ostensive and performative aspects of routines enables endogenous changes in routines (Feldman & Pentland, 2003); the ostensive aspect guides the performance, and the performance creates and recreates the ostensive pattern (Feldman, 2015; Pentland & Feldman, 2005). Although routine performances depend on their ostensive aspect, the particular courses of actions in practice are subject to improvisation and reflection as they are carried out by specific actors at specific times and places (Pentland & Feldman, 2005). One interpretation of this view is that practitioners enact routines from multiple (yet constrained) possibilities (Pentland & Rueter, 1994). That is, not only is the exact replication of a routine performance impossible (Pentland & Feldman, 2005), practitioners can mindfully deviate from some performative expectations (Feldman & Pentland, 2003). A review of empirical research on routines confirms that the dynamicity and change of routines is in part due to people's improvisation and reflective assessment as they perform them (Becker, 2004).

In addition to any endogenous changes of routines, organizations may develop or change routines in response to stimuli (Pentland & Feldman, 2005) or in pursuit of objectives such as improving performance or replicating best practices (Glaser, 2017). For example, after reflecting on previous performance, organizations may decide to repair their routines (to achieve new outcomes), expand them (to take advantage of new opportunities), or strive to improve them (to enhance continuous change) (Feldman, 2000). This reflective assessment is a backward-looking experiential learning behavior (Gavetti & Levinthal, 2000) that enables evidence-based reasoning about the efficacy of actions that practitioners introduce into their routines. However, on temporary projects, opportunities for such experiential learning (and, thus, changing routines) are limited by situated circumstances like custom initiatives, time and resource constraints, and the demands of multi-party coordination and decision making (Bygballe, Swärd, & Vaagaasar, 2016). Given such limitations that cause "selection pressure" in decision making (Gavetti & Levinthal, 2000), this study examines how project parties identify, reason about, and assess the efficacy of their responses to disruptive information exchange initiatives. In the case-study that follows, this paper frames inductive and abductive reasoning mechanisms of creating and articulating knowledge to respond to disruptive initiatives. With inductive reasoning, project parties created evidence-based knowledge and ground rules through reflective assessment of new workflows. With abductive reasoning, due to selection pressures, project parties relied on their cognitive judgements to generate new ground rules without actual evidence of their efficacy (Gabbay & Kruse, 2000; Reiss, 2011).

3-4-3- Research Gap and Points of Departure

The theoretical lens of routine dynamics holds that both enacting organizational routines and changing them require reasoning and knowledge processes. Enacting routines involves learning and reasoning based upon existing knowledge of routine triggers, events, and actions (Hodgson, 2009). Changing routines involves experiential learning and evidence-based knowledge of the efficacy of past performance (Feldman, 2000). The construction literature has also identified experiential learning as the mechanism through which practitioners change their information exchange routines (Kokkonen & Alin, 2016). In precis, the foregoing literature review shed light on experiential learning and reflective assessment mechanisms through which firms gradually adopt and adapt to innovations and change their information exchange practices.

Despite these insights, few studies have addressed the overarching empirical question in this paper: How do project parties perceive, interpret, and act upon information exchange requirements that disrupt their routines? This question has two important considerations. First, custom requirements do not necessarily demand long-term transformation of information exchange routines despite the initial disruption they cause. Second, time and resource constraints, further challenged by the immediacy and variability of custom requirements, can limit experiential learning opportunities within projects contexts. This unpredictable mix of limitations and possibilities evinces the importance of exploring reasoning patterns that underpin the perceptions, interpretations, and actions of project parties with respect to disruptive project requirements.

3-5 - Research Methods

3-5-1- Research Approach, Context, and Setting

Consistent with the thrust of research on routine dynamics, this study takes an interpretivist stance centered on the understanding of the thoughts, discourse, and actions that individuals attach to their experience (Mackay et al., 2001). Such a stance engenders in-depth inquiry into context-dependent phenomena and complex processes and interactions (Saunders et al., 2009). This approach, therefore, facilitates "practice" and "process" research that explores how and why elements of practice evolve in certain ways (Feldman & Orlikowski, 2011; Pettigrew, 1997). This line of inquiry is often best carried out through case-studies (Langley, 1999)

The U.S. construction market is highly innovative and prolific, yet fragmented, in producing custom information exchange guidelines, protocols, and mandates across industry bodies, government jurisdictions, and institutional owners (Kalin et al., 2011; Kassem et al., 2015). In the U.S., most firms tend to have short-term relationships with a large set of partners across projects. This variability makes it difficult for them to align their long-term information exchange practices. Consequently, project networks become the self-organizing frontlines where misalignment and conflict between existing routines and new information exchange requirements come to the fore (Taylor & Levitt, 2007). Given these vicissitudes, the U.S. construction industry is an ideal context within which to study how project parties perceive and respond to the custom information exchange requirements that disrupt their organizational routines.

To probe the question of how project parties experience disrupted routines in a natural setting, this research took a descriptive case-study approach (De Vaus, 2001; Yin, 2003). The selected case was a construction project, hereinafter called the Technology and Engineering Center (TEC; a pseudonym). The TEC was a 13,000 m^2 facility procured by a public institutional owner (using the General Contracting/Construction Management delivery method with a $115 million budget). This facility had a variety of functional spaces for teaching, research, and collaborative learning to support science, technology, and engineering fields. The owner enforced a series of highly customized transfer-to-operation (T2O) requirements for the production and handover of the following deliverables: (a) construction submittals (e.g., shop drawings, product data, and samples); (b) close-out submittals (e.g., redlines, as-built documents, operations and maintenance manuals, warranties, and training submittals); (c) digital bindings for operations and maintenance; and (d) facilities management (FM) data. These closely related requirements addressed the content, organization, formatting, storage, and transmittal of data and documents, and set out a timeline of milestones for information exchanges. With such highly custom requirements, this case is representative of an increasingly common issue on projects in the U.S. However, because of its varied and detailed information exchange requirements, its empirical setting is well-suited for addressing this topic through multiple narratives about a variety of routines and requirements (Flyvbjerg, 2006). As a theory-building approach, the use of multiple narrative facilitates the identification of patterns from data (Eisenhardt & Graebner, 2007).

The unit of analysis in this study was each firm who took part in the project for the whole duration of the construction stage. The bulk of data in this study was collected from six firms including the project owner, owner representatives, general contractor, mechanical contractor, and electrical subcontractor firms. This analysis streamlined the process of identifying intra- and inter-organizational routines within and across firm boundaries. To address the reliability and replicability of this case-study, the author prepared a detailed case-study protocol (Given, 2008; Yin, 2003). Parts of this protocol are reported in the following sections.

3-5-2- Data Collection

This research collected qualitative data by triangulating different data collection methods, data sources, and data types to ensure accuracy of findings for internal validity (Given, 2008; Yin, 2003). The data collection period spanned the project's 16-month construction stage, to fully capture the real-time work performed on T2O requirements. The primary data collection methods included ethnographic observation, artifact analysis, and interviews.

The ethnographic observation of bi-weekly on-site meetings provided data on multi-party coordination of the work on T2O requirements. Data were collected in various formats, including field notes, audio-recordings, and digital and physical artifacts from the meetings. To gauge the degree of stability or disruption in routines, the author collected and analyzed additional textual and visual artifacts (in both digital and physical formats) from the project parties. This additional analysis of artifacts further supplemented the data collected through observations and interviews. These artifacts included contractual documents (e.g., specifications and submittals), *ad hoc* communications (e.g., emails), and screenshots and videos of workflows for submittal preparation, filing, and data storage.

Through interviews, this study obtained data on the internal routines, perceptions of the T2O requirements, and other project interactions not readily identifiable in project meetings or artifacts.

Snowball sampling was used to identify the informants. The author conducted a total of 18 initial and follow-up interviews (ranging in length from 30 to 60 minutes). The informants from the owner organization included the project manager, the T2O officer, and the FM data consultant. From the general contractor (GC), mechanical subcontractor (MC), and electrical subcontractor (EC), participants included project managers, assistant project managers, and project engineers. Their professional experience ranged from four to thirty years; and each had at least three years of experience working with their employer (ensuring their familiarity with their routines).

The semi-structured protocol for interviews comprised the following types of questions: (a) questions for identifying routines or dispositions applicable to information exchange; (b) questions asking how the work on the T2O requirements differed from existing routines; and (c) questions regarding the tasks and assignment of roles and responsibilities necessary for carrying out the T2O work. These questions combined the critical incident technique with the time-line interviewing approach to facilitate capturing concrete examples, extreme cases, and cognitive or procedural sense-making behaviors over time (Dervin & Frenette, 2001; Flanagan, 1954).

3-5-3- Data Analysis

After transcribing the recordings from the interviews and meetings, the author loaded all transcriptions and artifacts into the ATLAS.ti application for qualitative data analysis. Using the interpretivist approach, the data analysis process treated the data as proxies for experience (Ryan & Bernard, 2000). The first round of data analysis involved creating chronological narratives of critical incidents in the T2O work (Bernard, 2006; Lamont & White, 2005). These critical incidents involved instances in which project parties reported a need to better understand project requirements while questioning the scope, timeline, and allocation of work. Four narratives were created as tools for comparative analysis of how, over time, project parties attempted to plan, assess, and justify their courses of action in response to the T2O requirements.

After narrativizing the project parties' perceptions and responses, the author conducted a second round of data analysis, using descriptive and *in vivo* coding on the narratives to identify any themes emerging from the empirical actions taken to meet the T2O requirements. Through this process, events recurring across cases (first-order concepts) were identified and combined as themes. For instance, in one series of events, project parties referred to their knowledge of existing routines to question the intent of the new requirements and to connect them with existing practice.

In the third round of data analysis, the researchers used the constant comparison and systematic combining methods to establish the themes at a more abstract level and orient them within the context of the existing literature (Dubois & Gadde, 2002b; Kelle, 2010). For example, this analysis aimed to clarify whether the project participants used new or existing knowledge bases to plan, justify, and set ground rules for their information exchange workflows, and whether these knowledge bases were evidence-based or intuitive. These findings resonated with the literature with respect to how project participants perceive, interpret, and act upon project requirements that disrupt their routines. For instance, previous research has shown that evidence-based new knowledge is a result of the experiential learning mechanism through which organizations change or improve their information exchange practices (Kokkonen & Alin, 2016). Using experiential learning as a backward-looking learning behavior, people can evaluate the efficacy of actual performances. However, with the forward-looking cognitive search, they do not enact performances to evaluate them. Instead, they rely on their understanding of the world and probable consequences to justify their courses of action (Davies, Dodgson, & Gann, 2016; Gavetti & Levinthal, 2000). To better understand these differences in planning and problem-solving, this study framed the knowledge processes in terms of the deductive, inductive, and abductive reasoning mechanisms through which people create, use, and articulate knowledge. Using deductive reasoning, the project parties relied solely on their knowledge of existing routines and rule-like dispositions to verify the intent and question the feasibility of implementing project requirements. With inductive reasoning, they created new knowledge and ground rules through reflective assessment and experimenting with new workflows and role assignment. With abductive reasoning, project parties relied on their cognitive judgements to generate new ground rules without actual assessment of their efficacy (Gabbay & Kruse, 2000; Reiss, 2011).

The following section presents the empirical findings from the narratives in four vignettes. Each vignette addresses a subset of T2O requirements, the relevant inter- or intra-organizational routines, and the processes that reflect the ways project parties interpreted and acted upon the requirements. Throughout the vignettes, the emphasis is on the reasoning mechanisms and knowledge processes that the project parties used to assess the efficacy of their workflows and set ground rules for action.

3-6 - Findings

3-6-1- Vignette I: Bind, Break, and Re-assemble Submittals

The construction submittal routine for project parties entailed aggregating the documentation needed for design and construction, and then transmitting the submittals to an upstream project party for review and approval. For example, vendors would provide cut sheets and samples to subcontractors; subcontractors would prepare submittals for the GC; and the GC would transmit submittals for architect, engineer and owner review. After receiving approvals for and completing the work, each party was required to update and re-transmit the submittals (as well as operations and maintenance documentation) to the upstream party for project close-out. (See Figure 5.)

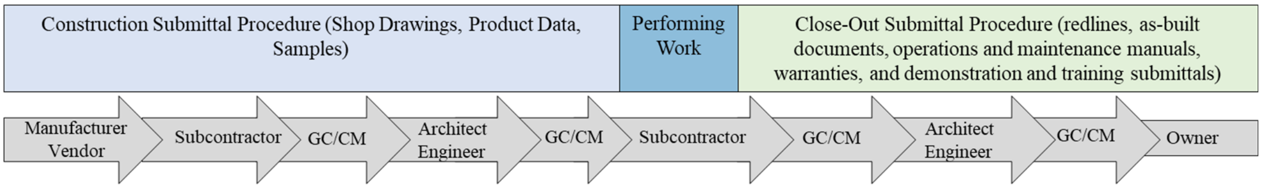

Figure 5 – Routinized Pattern for Inter-Organizational Submittal Exchange

In addition to the inter-organizational routine for submittal exchange, each party had internal routines for submittal production and exchange. For instance, from a subcontractor's perspective, the MC had a "standards team" in the regional office that collected information from suppliers (e.g. vendors or manufacturers) and prepared and maintained "typical" submittal documents for use across projects. The project engineers then used these standardized documents and appended project-specific information to the submittals. For custom equipment and made-to-order products, the project engineers handled the entire submittal preparation process after reviewing drawings and specifications, coordinating with vendors, and gathering supplementary information. The MC used specialty software, internal digital repositories, submittal templates, and workflows that guided project engineers through this process. In this way, this submittal production process shaped a routine that began in the regional office and continued with the work of project engineers to compile all information. After gathering all the information, the project engineers then submitted these documents to the general contractors for review and approval.

This vignette shows how the extensive requirements for naming, formatting, organizing, and transmitting digital submittals disrupted re-enacting these routines. For example, the contractors were accustomed to "binding" the submittal documents together, but the T2O specification required them to "break up" the "composite" files into individually named files and then cross-reference them. The owner asked for individual files according to a custom breakdown, folder organization system, and naming convention. Even for “big files that vendors sent over,” the contractors were to “break” the files apart in accordance with the requirements:

> *[This set of T2O specifications] is unique to [the owner];…typically we have an electronic close-out procedure, it essentially includes a workflow for gathering, binding, and submitting all final documents electronically; that’s something we provide, but we do not have such a detailed standard for it* ***(Interview - Project Engineer for GC).***

These findings show that both intra- and inter-organizational routines were at play for submittal production and exchange; each party worked with the upstream and downstream parties for submittal exchange, review, and approval, and had their own internal routines (e.g., procedures, tools, and templates) for producing and organizing submittals. Without a “detailed standard,” these routines and workflows satisfied submittal requirements on conventional projects, since these parties were given latitude in how they organized information in their submittals. Therefore, despite their flexibility in establishing their internal routines (e.g. templates, repositories, processes), they aligned these routines with the inter-organizational submittal exchange routines.

Initially, the project parties referred to the ostensive pattern of their existing routines to guide their work on the new requirements. For instance, the subcontractors attempted to address the requirements early on during the construction submittal procedure (See Figure 5). However, they identified and voiced concern about the conflicts between the routine submittal procedures and the requirements. They noted that they still had to follow their routines (using their typical submittals, templates, and repositories) to ensure that the submittals were consistent with their firm’s standards, workable internally, and packaged for conventional project reviews by the upstream parties; but they also needed to take separate steps for breaking apart, renaming, and organizing documents into individual files to meet the owner’s close-out requirements. The project parties further discussed how these requirements differed from their existing routines in terms of scope, tasks, roles, and responsibilities. They often referred to rule-like components of their routines to question and verify the intent of the T2O requirements. The following references to such rule-like components discussed in a project meeting:

[with these specific folders for the subcontractor submittals,] who is actually going to be doing this transmittal of submittals [to the owner]? What I have seen in other projects is that [GC's] commissioning manager uploads the submittals; subcontractors did not upload the files directly" ***(Assistant Project Manager for GC)***

I am not sure yet. We have to work on a workflow to test it out. We have created folders for the subcontractors, but [the GC] may want to do all the updates in the repositories ***(Owner's Representative)***

These findings show that the contractors deductively used the ostensive elements of their routines (e.g., roles, responsibilities) to guide and justify their actions. When they recognized the conflicts between these elements and the new requirements, they reconciled their knowledge of existing routines with their emerging knowledge of the new requirements by validating the ostensive elements of the routines (e.g., determining who transmits data to whom).

The highlight of these coordination meetings was the decision to "test out" workflows to experiment with new processes, roles, and timelines for the work. The team worked on a selection of close-out submittals as early as possible (at approximately 30-percent completion of construction). The goal was to understand how they could assign responsibilities and develop the timeline for addressing the requirements (e.g., either as they prepared the construction submittals or after all submittals were approved). Because these experiments revealed that each subcontractor had a different understanding of the requirements, it was clear that preparing consistent submittals across all parties posed a significant challenge:

> *Some requirements differed from what we understood; e.g., placing certain information on a document and referencing it on others, or breaking and naming documents; we needed lots of feedback to figure out and flesh out submittals* ***(Interview - Project Engineer for MC).***

Through these recurring experiential learning cycles, the project team inductively identified the inefficiencies and misunderstandings, and planned their course of action for meeting the submittal requirements (e.g., through recurring feedback loops). In one example, in order to avoid multiple review cycles or re-work on revised documents, the contractors chose to address the naming, formatting, organization, and transmittal requirements just before the final close-out submittal (see Figure 5). Accordingly, after a submittal approval process on “composite” files, the GC had the subcontractors break apart the approved documents in accordance with the required breakdown and contents. However, once the significant differences in the subcontractors’ understanding of the requirements became clear and persisted despite the feedback cycles, in a turning point, the GC chose to take responsibility for addressing the file naming convention and organization for all submittals. This substantial shift in the workflow shows that the contractors selectively buffered each other from some requirements to avoid inconsistencies, additional feedback loops, and rework. In sum, the disruption of existing routines led to additional cycles of submittal turnaround between the GC and subcontractors, an increased scope of work, and re-allocation of roles and responsibilities for submittal production and exchange. While it was not surprising that the contractors had to change many performative aspects of their routines, this vignette shows that the work generated in response to disruptive requirements disrupted the more fundamental ostensive aspects of routines (e.g., roles and responsibilities, and patterns for submittal turnaround cycles).

3-6-2- Vignette II: "Kind of Similar, Kind of Different"

In addition to the team of project engineers responsible for submittal production (discussed in Vignette I), the MC had a specialty start-up team focused on equipment start-up, testing, and commissioning. This team's procedures shaped a pattern for start-up routines implemented across the MC's projects. In terms of their sequence and timeline of involvement, "when anything is installed and ready to operate, the start-up team show[ed] up to test and run equipment" (Interview of MC Project Engineer). The start-up team collected a variety of data on equipment and took pictures of it for internal use and inclusion in submittals. Therefore, some data collected by this team could be used for FM purposes (operations and maintenance). However, this team did not directly participate in submittal production and exchange on any of the projects; the project engineers regularly took over its data and files and used them in the submittals. The project engineer's use of the start-up team's equipment data revealed the overlap and interdependency of the start-up and submittal production routines.

This vignette shows how the FM data requirements of the case-study project disrupted the submittal production routines of the MC. The FM data requirements specified custom details for the development schedule, contents, formatting, and storage of this data. These requirements conflicted with the data collection procedures of the start-up team's routine. For instance, the owner required four stages of data collection and transmittal: (1) construction start, (2) construction submittal approval, (3) equipment installation, and (4) construction close-out. However, the start-up routine across all MC projects would be triggered after equipment installation. Also, the routine scope of start-up data collection did not include custom T2O data;

for example, special attributes for equipment (e.g., identifying parts, belts and filters), a custom naming convention for equipment; and additional references to submittal documentation (as discussed in Vignette I).

Early on in the project, the contractors recognized the similarities between the ostensive aspects of start-up routines and the suggested tasks for FM data collection; both entailed similar patterns for collecting equipment data (e.g., reading name-plate data and taking installation photos). With these general similarities, the contractors deductively justified that collecting FM data during start-up activities would draw on the existing data collection routines. Since the start-up routine would not be triggered before equipment installation, the MC referred to this routine on several occasions to determine whether the owner would allow the synchronization of the specified data collection timeline with the start-up routine to prevent redundant data collection efforts:

> *We can get the installation data off the equipment; our start-up team would grab data and populate [it] in our cloud platform; [...] and that will not change the timeline for [close-out] submittal. That way I would use those start-up data and sheets instead of going through all information right now.* ***(Project Meeting – Project Manager for MC)***

> *It is the timing of collecting data. Perhaps that can be months down the road once it is installed and commissioned. It is going to be a time-consuming effort to grab some data early.* ***(Project Meeting – Project Engineer for GC)***

With these discussions, the project parties began reasoning about the feasibility, advantages, and disadvantages of leveraging start-up workflows for FM data collection. The intent was to identify workflows that met the specified requirements without imposing duplicate efforts on the contractors. Accordingly, the project parties questioned whether data collection by the start-up team would be efficient for all participants, especially for project engineers, who had to take over start-up data and reformat it for submittals. The project parties used abductive reasoning mechanisms to plan and justify the efficacy of alternative workflows. As shown in the following descriptor, justifications were based on cognitive judgements rather than experiential evidence:

> *Getting data from the start-up team may make data collection more efficient, but I do not think using their files is ultimately efficient for extracting and reformatting data for the owner; and eventually we will need to plug data into the repositories; but we can reduce the doubling up of gathering data if the start-up guys can do some part of it [within the expected timeline].* ***(Project Meeting – Project Engineer for GC)***

With these abductive justifications, the project parties presumed that involving the start-up team in this process would have imposed additional data collection and coordination efforts on them. As the start-up team's routine entailed making a one-time data collection attempt for each piece of equipment, their presence on the job site could have been extended to re-collect data if their data were incomplete or did not satisfy the project requirements. For these reasons, the MC decided to give the project engineers the choice of using the start-up team's data only when it met the scope and timeline of the project. Thus, as in the situation in Vignette I, the work of project engineers was organized "out of routine" to satisfy the custom requirements (Project Meeting – MC Project Manager). The project engineers internally arranged experimental processes to "figure out" FM data collection. They noted that, for this effort, they spent "as much time as the start-up team spent for their routine data collection" (Interview – MC Project Engineer). Although having project engineers collect and organize the FM data imposed new roles and additional tasks into their existing submittal routines (e.g., accessing equipment on the job site to take photos and collect data), this arrangement buffered the start-up team from the work on disruptive requirements.

3-6-3- Vignette III: In-and-Out of Digital Territories

While each project party routinely used an internal digital repository for submittal production, they were used to accessing a conventional digital repository managed by their upstream party to transmit the submittals. As such, the project parties had an *a priori* ostensive disposition regarding how their submittal exchange routines should be enacted in digital repositories.

In the case-study project, the owner required the project parties to contribute to two data and document repositories in addition to the conventional project submittal exchange repository (SER). The operation and maintenance repository (OMR) was for organizing and accessing the breakdown of electronic close-out submittals. The facilities data repository (FDR) was for collecting, reviewing, and verifying FM data and photos, including data that referenced the file names in the OMR. This vignette shows how the requirement to work with these additional repositories challenged the existing routines by extending the presence and responsibilities of project parties into new digital territories.

Early on in the project, the contractors referred to the existing practice of using a single repository to deductively reason about the efficiency of keeping "all the information in one spot." However, the owner representatives argued that this three-part division of repositories was meant to support readiness for facilities management after project completion. They also argued that the contractors were well suited to manage the organization and flow of submittals across the repositories. The following excerpt from a project meeting represent these discussions:

> *Maybe we [the contractors] should put all the information in one spot as usual; so, we do not have to go to multiple places to maintain and pair files and data.* ***(Assistant GC Project Manager)***

We [the contractors] want to make sure we are not linking data to documents ourselves across the repositories; [the FM data consultant] will be able to establish the link for a particular asset in FDR and a document in OMR. ***(GC Project Engineer)***

I am anticipating the construction team making that link, as you have the name of submittal and equipment; I not am asking you to upload documents to FDR, but make that connection and say this OMR document connects to these 10 pieces of equipment in FDR. ***(FM Data Consultant)***

Over the course of the project, the project parties met in biweekly coordination meetings to discuss the status, organization, and progression of the submittals in the repositories. Some questions and concerns were addressed on the basis of the inductive reasoning and recurring reflective assessment of the work (e.g., determining at which stage and in which order particular files or data should be uploaded to each repository); and some outstanding concerns were handled by establishing alternative ground rules through abductive reasoning and cognitive searching for new workflows. For instance, feedback from the contractors revealed their continued difficulty updating data in the FDR. The team finally addressed this issue in a turning point when the FM data consultant took responsibility for uploading data into the FDR, thereby buffering the contractors from that requirement:

Because the way system works, if you import a file, you can override information with blank information […] I am now kind of the gatekeeper to make sure it goes smoothly. ***(Project Meeting - FM Data Consultant)***

These findings reveal a learning curve associated with the work on the additional repositories. Therefore, recurring coordination and feedback loops were found to be necessary to identifying and mitigating emerging issues. However, the concerns over the "multiple ways of collecting the same information" and maintaining up-to-date information across these three disconnected platforms were never completely resolved. The reason was varied requirements for breaking down, naming, and organizing the files across multiple internal and shared repositories (e.g., the composite submittal files in the SER; the individual submittal files in the OMR). The following descriptors captured these concerns regarding over the disruptive project artifacts:

> *I am struggling with figuring out how to communicate and make sure we know which document packages need to be broken [into individual files] and re-formatted, or how to communicate for example if there is a revise and resubmit, or data and documents in different repositories must be updated.* ***(Project Meeting – GC Project Engineer)***

> *It is all the same information, right? but it has to be directed to multiple places, GC's repository, Owner's repositories, etc. It is the same information that is being copied and renamed; we have our own repository for submittals too; so, there are multiple ways of collecting the same information in this project.* ***(Interview – MC Project Engineer)***

3-6-4- Vignette IV: Who Is Going to Pick Up the Change?

This vignette highlights the existing routine for processing change order directives during construction, wherein project parties revise and reissue their submittals to incorporate project changes. On the case-study project, the owner requested a major change to the function of some internal spaces, which necessitated the revision of electrical and mechanical equipment in these spaces. As required in the project, the architect was the responsible party for identifying the baseline list of spaces and equipment. However, given that the construction team had made progress in collecting submittal and installation data, they questioned whether they should halt data collection and wait for the designers to formally reissue the list of spaces and equipment. This hesitation showed that they were unclear as to how the change order processing routine should be enacted for an in-progress submittal that had been sequentially created by multiple parties.

In their conversations about changing the FM dataset, the project parties made direct references to the change order processing routines. The following excerpt from a coordination meeting shows how project parties referred to these routines as "normal course of activities:"

I need to have a discussion with [the owner] to see how that change order affects [the construction] team. I am sure there is information to be collected. ***(FM Data Consultant)***

The work was added as a change order, and I am assuming that we will collect data for any asset that is being added as a part of that change, like the normal work with any other change order … that is part of our normal course of activities. ***(Owner's Representative)***

This reference to the existing routines raised concerns among the construction team because the designers had not been actively involved in FM data coordination during construction. Thus, as shown in the following excerpt, the construction team abductively reasoned about the efficiency of "pulling the designers back" and carrying out the "normal work" on change orders. For instance, they pointed out the potential conflicts with their planned data aggregation workflows that were enacted out of routine (see Vignette II). They also discussed potential scenarios, ground rules, and the allocation of responsibilities for incorporating changes to the dataset:

Instead of pulling the designers back in and having them go over the drawings and identify items, like what we did initially, it would be most efficient if we [the construction team] look at the drawings and add assets to this spreadsheet. If there is no objection to that … I will pull out any data that fall under the changed scope. ***(FM Data Consultant)***

So to be clear on that, for any change, [the FM Data Consultant] will update the dataset *for any new piece of equipment; but if there is any change to the construction data points, the contractors have to update them. I am just trying to think how we are going to manage this and make sure somebody has a responsibility for it.* ***(GC Assistant Project Manager)***

*I would not like to be responsible for this if one piece of equipment is added and I am not aware. I would like the contractors [to] let us know if we add like one pump to a room. I am talking about just this change order, it would be more than one piece of equipment, so I will go through the effort of getting that equipment list updated. But little changes, like a pump being added, or something getting taken out, you all need to let me know if those changes happen so we can track data****. (FM Data Consultant****)*

These excerpts show the temporary shifts in reasoning and justification about the allocation of responsibilities for updating the dataset. This volatility revealed the abductive reasoning mechanism that ultimately led to the decision to create a new workflow and buffer the architect from the work. Based on these discussions, the subcontractors took the responsibility of updating the dataset for any subsequent change orders. However, tracking changes in the dataset remained a significant challenge for two reasons. First, the team needed to establish a new out-of-routine procedure to communicate the changes. Second, the responsibilities for changing the dataset were misaligned with those needed for incorporating the change into the FDR. For instance, the subcontractors had to change the dataset through a detached spreadsheet, while the data consultant was gatekeeping the process of loading these changes into FDR (see Vignette III). The following excerpt shows that recurring coordination and reflective assessment were necessary to verify the efficacy of this out-of-routine workflow and troubleshoot irregularities:

It looks like there [are] a few assets missing; there are some VAVs in the FDR but [they] *are not in the updated spreadsheet [you emailed ...]; it looks like some assets [were] removed or changed names.* ***(FM Data Consultant)***

The information in ASIs and RFIs changed the equipment names; this is to reflect those names; you will see some rows that show those changes and what the name was before; and some of them are future equipment and do not exist for the current scope of the project. ***(MC Project Engineer)***

Those are [the] changes that I would not be aware of and would have definitely confused the facility guys at the end of the project if we did not track this. ***(FM Data Consultant)***

3-7 - Discussion

3-7-1- Unpacking Perceptions of Disrupted Information Exchange Routines

The theoretical lens of routine dynamics through which the author approached disruptive information exchange marks a departure from the innovation adoption/organizational change perspective taken in the existing research (Whyte & Hartmann, 2017). The routine dynamics lens examines both the ostensive and performative aspects of routines. As abstract and durable patterns in routines, the ostensive aspect steers the performance of situated and specific routines (Feldman, 2015). Using this lens, the author developed four narratives that showed that the enacted performances deviated not only from the performative expectations, but also from the abstract and durable ostensive patterns of the existing routines. Routine dynamics theory accounts for deviations in performance through adjustment and improvisation in situated circumstances (Feldman & Pentland, 2003; Pentland & Feldman, 2005). Such improvisation is often carried out by skilled individuals who absorb any idiosyncrasies in requirements, to keep the routine patterns intact for others (Stinchcombe, 1990). However, in the narratives, none of the contractors or individuals could unilaterally absorb the work necessitated by the information exchange requirements due to the intertwining multi-party nature of information exchange routines. Consequently, the project participants temporarily reconfigured the durable aspects of their routines, making temporary shifts in the roles they assumed, re-allocating responsibilities, and modifying workflows for using and generating routine artifacts.

The literature on routine dynamics emphasizes that the roles and responsibilities of individuals in routines can shape their point of view toward the context, tacit dimensions, abstract ideas, and performances of routines (Feldman, 2015). Therefore, this paper spotlights that substantial changes in organizational roles and responsibilities can undermine the validity of existing information exchange routines for project participants. This finding further reinforces the importance of analyzing information exchange disruptions "from within" and "from outside" organizational boundaries (Çıdık et al., 2017). For instance, in Vignette 2, disruptions in roles and responsibilities were presented only from a subcontractor viewpoint; however, in other vignettes, a project network viewpoint was needed to identify disruptions in inter-organizational roles and responsibilities.

As for the disruption of routine artifacts, the findings support the routine dynamics propositions that artifacts can account for the ostensive aspect of routines when they are guides or resources for actions (Pentland & Feldman, 2005). The narratives revealed that routine artifacts, such as digital repositories (Vignette III) and document templates and bindings (Vignette I) were indeed mentioned as references for routines. In contrast, the custom requirements for artifacts imposed additional pressure on project participants to plan, justify, and coordinate their actions. This observation further corroborates the findings of previous AEC research that found routine artifacts to be durable components that cannot be easily substituted or changed in their ecologies of practice (Harty & Whyte, 2010).

In summary, when firms cannot improvise their performance within the constraints of routine patterns, their responses to custom information initiatives can undermine durable roles, responsibilities, artifacts, and thus, overall performance. The following section discusses the underlying reasoning mechanisms and knowledge processes of these organizational responses to disruptive information exchange initiatives.

3-7-2- Unpacking Reasoning Mechanisms Used in Disruptive Circumstances

3-7-2-1- Deductive Reasoning

The study found that, when challenged by new requirements, project parties continually refer to and draw on their knowledge of information exchange routine tasks (e.g., submittal production and exchange Vignette I, collecting equipment data in Vignette II, using digital repositories in Vignette III, and processing change-orders in Vignette IV). These attempts to exploit their experience helps them ascertain the discrepancies between existing routines and new requirements and question the feasibility of using existing routine capabilities in the work on new requirements. This observation empirically established that referring to existing knowledge of routines is a way to question or legitimize actions demanded by requirements (Feldman & Pentland, 2003). This further explains why practitioners constantly weigh high-level concepts like standard of care and professional requirements against information exchange initiatives on projects (Abdirad & Dossick, 2019a; Poirier et al., 2017). Furthermore, the attempts to validate abstract ideas and rule-like dispositions can be explained by the fact that routines have pre-coordinated responsibilities that minimize the need for planning, coordination, negotiations, and deliberation over the work (Hodgson, 2009).

This paper proposes that such attempts to identify discrepancies between existing and new practices are *deductive* in nature, since they involve reasoning based solely on accumulated knowledge and rule-like patterns in routines. When these knowledge and patterns do not allow the practice to absorb new requirements (i.e. improvisation; Pentland & Feldman, 2005), project participants use inductive and abductive reasoning to shape new ground rules for practice.

3-7-2-2- Inductive Reasoning

The narratives developed for this study showed that the project participants used a series of inductive and abductive reasoning mechanisms to expose inefficiencies in their new work requirements, and then set alternative ground rules for action. In the narratives, inductive reasoning entailed using evidence to identify inefficiencies in the workflows; the conclusions from this reasoning, in turn, shaped the necessary adjustments made to the ground-rules (e.g., experimenting with the workflow and timeline for repackaging and renaming submittals or Vignette I; experimenting with the work on multiple repositories in Vignette III). This reasoning step in a broad sense is consistent with the backward-looking experiential learning and reflective assessment mechanisms that are conceptualized in the literature on organizational change (Gavetti & Levinthal, 2000); indeed, the routine dynamics theory recognizes this mechanism as a precursor to changing organizational routines (Becker, 2004). AEC research has also empirically shown that reflective assessment in information exchange practices facilitates adaptation to information exchange initiatives (Kokkonen & Alin, 2016). Such reflective assessment is also essential for balancing the burdens of new information exchange processes among concerned parties (Whyte & Hartmann, 2017). However, as discussed in the following section, the literature on information exchange in the industry has fallen short of recognizing occasions when inductive reasoning is not feasible or when path-dependent reflective cycles fail to generate the expected results.

3-7-2-3- Abductive Reasoning

The case-study narratives showed that project participants sometimes did not initially use inductive reasoning and reflective assessment (e.g. Vignettes II and IV). Moreover, at some critical moments, project participants abandoned inductive reasoning and reflective assessment cycles to set new ground rules for actions (e.g. Vignettes I and III). On these occasions, the project parties used abductive reasoning mechanisms to generate new practices and speculate about their efficacy (after cognately assessing potential scenarios). This abductive reasoning mechanism is consistent with the cognitive search approach in the literature on organizational change (Gavetti & Levinthal, 2000). The critical incident technique and timeline analysis of the events chronicled in the narratives showed that the inefficacies of feedback loops and/or the urgency of project milestones drove the project parties to use abductive reasoning. For instance, the contractors were stuck in the feedback cycles and unable to understand and address some requirements (e.g. using new file-naming conventions in Vignette I or developing the best process for uploading data into multiple digital repositories in Vignette III). In other examples, in Vignettes II and IV, the project parties had to make swift decisions on assigning roles and allocating responsibilities for collecting data and incorporating project changes into the dataset. These observations provide empirical evidence of the presence and effect of selection pressure, i.e., the felt need to make the identification of viable alternatives more critical than in regular circumstances followed by the resulting impulse to favor cognitive search (Gavetti & Levinthal, 2000). As discussed in the following section, responses generated through cognitive search and, by extension, abductive reasoning can significantly affect information exchange workflows in disruptive circumstances.

3-7-3- Unpacking Durability and Distance of Responses to Disruptive Requirements

The narratives presented in this paper showed that the alternative practices generated through abductive reasoning were substantially different from the existing practice (e.g., substantially shifted roles and responsibilities in all vignettes) and from each other (e.g., when multiple alternatives were generated in Vignettes II and IV). This observation empirically supports the presence and effect of distant search for alternatives through cognition (as opposed to local search in experiential learning; Gavetti & Levinthal, 2000). In particular, this case-study highlighted some unexpected attempts to assign roles and allocate responsibilities by “buffering” some project parties from some information exchange processes. For instance, in Vignette I, the GC buffered the subcontractors from certain requirements for submittal organization and naming; in Vignette II, the project engineers buffered the start-up team from the data collection and coordination processes associated with equipment data; in Vignette III, the FM data consultant buffered the construction team from data submission processes; and in Vignette IV, the architect was buffered from incorporating changes into the FM data repository. These examples show that the parties normally responsible for these tasks (in accordance with the existing dispositions) were shielded from the work to mitigate the overall inefficiencies associated with waiting for information, verifying the work, and correcting errors.

As discussed in previous sections, long-term change and adaptation in organizational routines occur through inductive reasoning that is based on reflective assessment (Feldman, 2000). However, the findings of this case-study show that many deviations and shifts away from the existing practice stand as work-in-progress remedies. None of these practices were intended to build or improve on the existing routines in organizations. Indeed, they lacked the capacity and durability to be efficiently replicated in different contexts, because they were generated in response to custom initiatives, situated circumstances, and selection pressure. This observation further confirms the propositions propounded in the literature on organizational change that alternative practices generated through cognitive search are prone to losing the experiential knowledge accumulated from the existing practice (Gavetti & Levinthal, 2000).

These results comport with the findings of previous research showing that the experience of specific instances of change in information exchange practices can shape systemized and simplified practices that are situation-specific and hard to challenge (Çıdık et al., 2017; Whyte & Hartmann, 2017). However, in contrast to these studies' presumptions that such practices further drive the change of information exchange practices in organizations and in the industry (Çıdık et al., 2017), this study clarifies that not all deviations have enough efficacy and durability to contribute to the enduring changes to intra- and inter-organizational routines. As such, these practices are often temporary and siloed attempts to accommodate time-pressured disruptive initiatives on projects. This observation can provide insights into why implementing some information exchange initiatives leads to unanticipated diffusion paths (Harty, 2008) and imbalances in the structuration of processes for different project participants (Whyte & Hartmann, 2017). The vignettes presented here show that practices generated in response to custom initiatives are prone to such unpredictable results, and that these knock-on effects then necessitate recurring coordination sessions (e.g. Vignettes III and IV) and rework for project parties (e.g. Vignettes I and II). These findings further support the idea that such practices lead to increased coordination only to troubleshoot information exchange idiosyncrasies, rather than producing better design and construction products through collaboration (Çıdık et al., 2017; Whyte & Hartmann, 2017).

3-7-4- Research Limitations

The unique empirical context of the project helped this research identify the existing routines and the patterns of perception and response to the new requirements. This information-oriented case (Flyvbjerg, 2006) aims to make a grounded analytic contribution (De Vaus, 2001) to the research in this area, by showing how the project parties in the selected case actually handled disruptive information exchange requirements. However, because it is only a single case-study, it does not aim to offer any statistical generalizations. Given its interpretive stance, despite capturing in-depth narratives, this research is also limited by the intersubjective accounts of the project participants and those of the researchers (Mackay et al., 2001). These limitations establish the boundary conditions for the propositions offered in this research. These boundary conditions include the following: (a) studying organizational routines (and their disruptions) within a short-term multi-party project context, (b) studying externally enforced project requirements as exogenous stimuli for revisiting the routines; (c) studying a series of highly custom requirements not commonly implemented on construction projects; and (d) studying certain kind of information exchange routines and requirements. Further studies should therefore take these boundary conditions into account and determine whether alternative conditions evince different patterns of perception and response to disruptive information exchange initiatives.

3-8 - Conclusions

This research found the reasoning mechanisms that project parties used to interpret disruptive information exchange requirements, expose inefficiencies in the work on the requirements, and set new ground rules for actions. Three reasoning mechanisms surfaced in four different narratives: deductive, inductive, and abductive. With deductive reasoning, project participants relied on the rule-like patterns in their existing routines to ascertain the discrepancies between existing practice and new requirements. Using inductive reasoning, project participants enacted reflective assessment cycles through recurring performances to make evidence-based adjustments to their ground rules for action. Through abductive reasoning, project participants formulated new ground rules for action through cognitive search in their response to the selection pressures (generated from the inefficiency of feedback loops and the urgency of project milestones). From this observation, this paper concludes that the temporary nature of construction projects limits the opportunities of project parties to balance their use of abductive and inductive reasoning mechanisms. Therefore, they are likely to identify and enact solutions that are temporary in nature, highly divergent from existing routines patterns and feedback loops, and therefore, not durable and effective to contribute to refining information exchange routines within and among firms.

3-8-1- Implications for Research

The key contribution of this paper to research is the empirical conceptualization of the deductive, inductive, and abductive mechanisms that underpin the perceptions and responses of project parties toward disruptive information exchange initiatives. Specifically, it is revealing to see how these mechanisms affect the stability and dynamicity of these responses (through invoking existing or new knowledge), and to note their proximity to or distance from existing practices (through local reflective assessment or distant cognitive search). By revealing these mechanisms, this study complements earlier research that addressed the impact of information exchange initiatives on firms (Çıdık et al., 2017; Poirier et al., 2017; Whyte & Hartmann, 2017).

This study contributes to the research on information exchange in the industry also by adopting the theoretical lens of routine dynamics. The AEC literature has rarely looked through this theoretical lens despite its valuable conceptualizations of stability and change in organizational routines. By adopting this theoretical lens, this study departs from the organization theories that dominated the research on information exchange initiatives in the industry. These theories include but are not limited to the following: actor-network theory; incentive theory; innovation theory; organizational change theory; and the technology acceptance model (Çıdık et al., 2017; Harty, 2008; Harty & Whyte, 2010; Papadonikolaki, 2018; Poirier et al., 2017). Examining disrupted information exchange routines through the lens of routine dynamics theory enabled this research to consider both durable routine patterns and situated performances; in turn, this insight helped this research identify temporary and transient practices that are often ignored by researchers working from macro-level perspectives on information exchange initiatives.

While most research on information exchange in the construction industry has focused on digital transformation with an emphasis to BIM implementation (Whyte & Hartmann, 2017), this study emphatically cautions future research on the necessity to better understand the many custom information exchange initiatives that propagate non-standard requirements, technologies, processes, and media. Hence, this study serves as a pioneering research that shed light on the importance of embracing a broader perspective on information exchange. This research studied custom information exchange initiatives that required project parties to navigate a multiplicity of new practices for generating and exchanging heterogeneous information exchange artifacts (e.g., submittal documents, facility datasets, and digital repositories). This further substantiates the importance of identifying and unpacking the interconnected information exchange routines to better understand the impact of disruptive initiatives on project parties in future research.

3-8-2- Implications for Practice

The existing research has called upon project owners to have flexible requirements that allow project parties to enact their multitude of information exchange practices (Whyte & Hartmann, 2017). This study, however, cautions the practitioners that the growing trend of implementing custom initiatives on projects continues to undermine inter- and intra-firm information exchange routines. This trend results in temporary and emerging workflows that demand costly coordination to troubleshoot irregularities, without enabling their routinization. For practitioners, this observation suggests that the disruptive impact of custom initiatives may not be efficiently absorbed by the performance of existing roles, responsibilities, and processes. It thus calls for an openness toward a variety of alternative processes and developing capacities for agile information exchange practices. For example, for practices within firms, flexible roles and versatile workers can buffer routine participants from the process idiosyncrasies caused by disruptive initiative. For inter-firm practice on projects, buffering partners from certain disruptive requirements can significantly facilitate adopting and adapting to information exchange initiatives.

Chapter 4 - Genericity-Complexity Tradeoff in Information Exchange Routines: Case of Disruptive BIM Cloud Collaboration Protocols

4-1 - Summary

The challenge for AEC firms to align with an unprecedented variation of digital information integration initiatives across projects is a recent phenomenon. The literature has so far offered only a partial understanding of this issue because of a focus on individual or unrelated project networks in isolation from other organizational constellations in each firm such as portfolios and operations (business functions that are not tied to specific projects or portfolios). Drawing on a two-year long ethnographic study of an engineering firm, this paper marks a departure from the existing research and explores how firms perceive and respond to the surge of custom project initiatives that disrupt information exchange routines in their practice. By looking at and beyond projects that required custom BIM Cloud Collaboration initiatives, this study found that project requirements disrupted routine ideas, artifacts, and processes with some effects that overreached project boundaries, thereby impacting portfolios and operations. With this evidence, this paper spotlighted the shifting loci of information integration in practice, wherein custom initiatives pressure practitioners to shift the focus of their information integration from their more permanent practice at firms to temporary projects. This study revealed the response mechanisms that practitioners enacted to manage this phenomenon and introduced the concept of genericity-complexity trade-off in information exchange routines to explain how firms generate practices that either address information

integration issues with ad hoc responses in projects or systemize information integration efforts within and among different organizational constellations.

4-2 - Introduction

Digital project delivery in the Architecture, Engineering, and Construction (AEC) industry has gained much attention and traction as an important emerging phenomenon. On the one hand, it has a revolutionary impact on organizations as it brings innovative technologies, new capabilities, and transformational workflows into their practice (Lobo & Whyte, 2017). On the other hand, when implemented collaboratively in projects, it has a disruptive impact on organizations because of heterogeneity and fragmentation of information exchange practices (Abdirad et al., 2020; Papadonikolaki, 2018). In fact, firms as business units tend to develop and maintain their digital information exchange routines independently from their counterparts because flexible institutional rules and short-term project relationships give them room to explore divergent practices (Bresnen et al., 2005; Harty, 2008). Therefore, strategies, motives, and practices for digital information exchange are often inconsistent across firms (Papadonikolaki, 2018). Digital information exchange routines, however, are important for reinforcing endogenous productivity in firms because they govern the ideas, artifacts, and processes used for generating information and exchanging information media (Harty, 2005; Harty & Whyte, 2010).

To align or connect the diverging practices and routines across organizations, the industry has set forth the concept of "information integration" to promote sharing information in project networks by consolidating information from different parties, technologies, tools, and processes (Kang et al., 2012). In particular, using custom information integration agendas for each project (e.g. Digital Delivery Execution Plans) has gained momentum in practice to focus on project outcomes by specifying file exchange formats, Building Information Modeling (BIM) platforms, and other data environments (Papadonikolaki, 2018). However, the growing proliferation of disparate information integration agendas across regions, projects, and stakeholders has further fragmented practices and given rise to custom and idiosyncratic information exchange requirements that undermine enactment of routines in firms (Abdirad et al., 2020; Kassem et al., 2015).

This challenge for firms to concurrently align with an unprecedented variation of disruptive standards, requirements, and processes for digital project delivery is an under-researched recent phenomenon (Papadonikolaki, 2018). Much research has studied how firms adopt digital project delivery capabilities and adapt to disruptive initiatives by focusing on individual or unrelated project networks (e.g. Abdirad et al., 2020; Çıdık et al., 2017). However, studying individual project networks in isolation from other networks and organizational constellations (e.g. portfolios and operations) offers only a partial understanding of the ongoing challenge for firms to address divergent and potentially incompatible information exchange requirements in their practice. Despite being temporary and unique, project networks in a firm potentially share ideas, resources, artifacts, and processes with one another as a part of routines enacted in portfolios and operations. Given the prevalence and importance of the custom information exchange initiatives for projects and firms, it is thus of both theoretical and empirical significance that we understand occasions in which these exogenous forces not only disrupt routines in projects but also undermine routines that practitioners enact at other organizational constellations.

With a longitudinal case-study of an engineering firm with a large portfolio of projects, this paper explores *how firms perceive and respond to the surge of disparate information exchange initiatives that affect routines at different constellations of their practice*. By looking at and beyond projects of this firm, this study uses a practice lens (Feldman & Orlikowski, 2011) to delve into the work carried out in response to a stream of custom BIM Cloud Collaboration protocols that a multitude of clients enforced on projects. By doing so, this paper makes a number of noteworthy contributions to research on information exchange in the AEC industry. First, it shows the response mechanisms that practitioners enact to address disparity and incompatibility of custom initiatives. Second, it spotlights the shifting loci of information integration in practice as custom initiatives increasingly pressure practitioners to shift the focus of their information integration from their more permanent practice at firms to temporary workflows in projects. This in turn brings new challenges for firms to generate, share, find, access, and control information internally among their projects and staff. Finally, this paper introduces the concept of genericity-complexity trade-off in information exchange routines to explain how firms generate practices that either address information integration issues with ad hoc responses in projects or systemize their management within and among organizational constellations.

4-3 - Theoretical Background

4-3-1- Disruptive Forces Affecting Organizational Practice

Within the sprawling organization literature, different theoretical threads address the influence of external forces on organizations (Smets, Greenwood, & Lounsbury, 2015). The institutional theory has recognized the social roles, behaviors, norms, and expectations that structure the external environment of organizations and constrain them with the common frames of reference or the so-called "rules of the game" (Giddens, 1979; Thornton & Ocasio, 2008). These external forces play a significant role in organizational "isomorphism" since pressures to conform to demands from powerful organizations (coercive forces), follow professional standards (normative forces), or copy other organizations (mimetic forces) lead to similarities in practice across organizations (DiMaggio & Powell, 1983). Despite this early characterization of institutional forces as sources of similarity and stability (Smets, Greenwood, et al., 2015), the institutional theory later embraced the concept of institutional complexity (Greenwood, Raynard, Kodeih, Micelotta, & Lounsbury, 2011), wherein multiple and often competing institutional forces (or institutional logics) create incompatible behavioral templates for organizations and engage them in institutional work, i.e. institutional creation and change (Smets, Greenwood, et al., 2015). However, this perspective emphasizes the institutional life of "an aggregate" of organizations and their episodic change or stability due to "macro-level" external forces; thus, the institutional view, detaches itself from additional forces that are able to impact organizations but are not "institutionalized" (Smets, Greenwood, et al., 2015; Wooten, 2015). Therefore, to understand how each organization responds to external forces like custom project requirements, there is a need to examine the seemingly mundane practices by which practitioners dynamically respond to situational exigencies (Abdirad et al., 2020; Smets, Jarzabkowski, Burke, & Spee, 2015). Accordingly, this paper applies a practice lens to account for the interacting macro (institutional), meso- (inter-organizational), and micro-level (intra-organizational) forces of change, stability, and disruption in everyday AEC practice.

The practice theory concerns the interface of human agency with the social world, and it acknowledges the interacting forces that pressure organizations from different directions (e.g. projects, firms, fields, institutions). Despite the variety of exogenous forces that influence practices, human agency enables practitioners to generate and reproduce their ideas and actions in response (Wenger, 1998; Wenger & Snyder, 2000) and even put these forces in a continuous state of transformation by "engaging" in mutual processes of negotiating and forming the organizational trajectories (Giddens, 1979; Wenger, 1998). In some circumstances, however, external forces pressure practitioners to align their internal actions and resources to exogenous forces without being actively engaged in forming them (Abdirad & Dossick, 2019b; Wenger, 1998). For instance, leveraging contractual relationships to demand conformance to requirements is a common way of exerting meso-level external forces on organizations (Austen-Baker & Zhou, 2014).

The challenge that practitioners face in responding to these forces is three-fold. First, these forces may disrupt organizational routines as the primary sources of productivity and endogenous improvement in practice (Abdirad et al., 2020; Berente et al., 2016). Second, being enforced from different directions (e.g. stakeholders, clients, authorities), these forces may be different or even be incompatible in what they demand from practitioners (Smets, Jarzabkowski, et al., 2015). Third, from a temporal standpoint, the persistence and durability of forces may vary (e.g. temporary project requirements vs. institutional norms; Abdirad et al., 2020). Accordingly, this paper aims to explore occasions in which AEC firms perceive and respond to temporary project requirements that impose diverging forces of disruption onto their organizational practice.

4-3-2- Forces of Stability, Change, and Disruption in AEC Information Exchange

Practice in the AEC domains involves different organizational constellations (e.g. industry, firms, project networks), wherein complex external macro- (institutional) and meso-level (inter-organizational) forces impact firms as business units (Abdirad & Dossick, 2019b). In these constellations, the interdependencies or couplings among firms significantly vary. In one-off and unique project networks, firms have a temporary tight coupling to adapt with project specificities and meso-level forces (Dubois & Gadde, 2002a). Beyond the scope and timeline of individual projects, firms have a loose coupling as they become less dependent on other firms in how they carry out internal work and adapt to general business complexities. In fact, firms strive for independency to establish internal routines in their work to enhance their stability and productivity across projects (Bresnen et al., 2005; Dubois & Gadde, 2002a). However, firms are not completely independent because this loosely coupled system of firms is still bound by a common culture, behavioral templates, and collective norms that shape macro-level institutional forces in the industry (Dubois & Gadde, 2002a; Thornton & Ocasio, 2008).

In this industry context, information exchange has received significant attention in research and practice. This is because project networks are complex nexuses of communication, wherein multiple parties generate and exchange a large amount of information across organizational boundaries and disciplinary divisions (Zhou et al., 2016). Although the foci of AEC information exchange lay within projects boundaries, research shows that firms independently routinize internal information exchange processes as they address macro-level norms and "accepted ways" of information exchange in the industry (Abdirad et al., 2020; Harty, 2008; Harty & Whyte, 2010). These norms generally address communication media (e.g. paper, digital or physical models) and different symbolic and iconic representation means (text, graphics) used to express technical information (Bretz, 1971; Tzonis & White, 2012). However, these norms in the industry often provide firms with a bare minimum template for work (Dubois & Gadde, 2002a), giving practitioners much slack to explore micro elements of their internal information exchange processes, media, and technologies as they routinize their practice (Harty, 2005; Harty & Whyte, 2010). Given this flexibility to establish internal routines, the day-to-day practice of information exchange has become varied and often inconsistent across firms, leading to calls to institutionalize information exchange prescriptions for consistent practice across the industry (Hooper, 2015).

With the evolution of digital technologies such as BIM, institutionalizing and regulating information exchange became even more challenging because of the heterogenous processes, tools, and standards that practitioners use to create, organize, format, store, and exchange digital information among project parties (Abdirad et al., 2020). Similarly, strategies, motives, and practices for BIM implementation are often incompatible across firms despite the emerging multi-party efforts to implement BIM in projects collaboratively (Papadonikolaki, 2018). To align or connect divergent practices, the industry has set forth the concept of "digital information integration" to promote sharing information between project participants and consolidating project information from separate technologies, tools, and processes (Kang et al., 2012). However, a review of recent BIM standardization efforts show that a variety of BIM guidelines (descriptive and optional), protocols (prescriptive and optional), and mandates (prescriptive and obligatory) have created multiple, yet fragmented, information integration agendas across regions, projects, and stakeholders (Charef et al., 2019; Kassem et al., 2015). Consequently, these disparate information integration agendas gave rise to custom and idiosyncratic requirements that disrupt information exchange routines in firms (Abdirad et al., 2020; Kang et al., 2012).

This challenge for firms to align with an unprecedented variation of BIM standards, requirements, and processes in projects is a recent phenomenon (Papadonikolaki, 2018). The lack of institutional norms for digital information exchange left gaps for firms to explore and generate alternative practices and agendas (Taylor & Levitt, 2007). With this trend, firms continue to face fragmented and disruptive project requirements (Abdirad et al., 2020). While we know that individual projects are often the front-lines for addressing such disruptions, we do not know whether and how higher organizational constellations such as project portfolios and operations in firms perceive and respond to the surge of information exchange idiosyncrasies. This paper investigates occasions in which custom information exchange requirements not only disrupt routines in project information exchange routines, but also undermine routines that practitioners enact at the portfolio and operations levels of their organization.

4-3-3- Organizational Routine Dynamics

Routines embody organizational knowledge and memory (Berente et al., 2016) and account for the majority of what organizations do in their practice (March & Simon, 1958). Thus, routines can produce stability in organizations while enabling change through potentially evolving enactments (Berente et al., 2016). The theory of routine dynamics addresses this duality of stability and dynamicity in routines. This theory explains that routines have ostensive, performative, and artifact aspects that impact the stability or dynamicity of routines as actors alter them in response to internal or external stimuli (Feldman, 2015). The ostensive aspect of routines is the general idea that enables people to guide, account for, and refer to specific performances of routines, while the performative aspect encapsulates situated actions that enable practitioners to create, maintain, and modify routines (Feldman & Pentland, 2003). The interaction of the ostensive and performative aspects in routines is analogous to that of agency and structure in the structuration theory (Giddens, 1979) and that of field and habitus in the practice theory (Bourdieu, 1977); the ostensive aspect guides the performance, and the performance recreates the ostensive aspect (Feldman, 2015; Pentland & Feldman, 2005).

As the last but not least component of routines, artifacts mediate between the ostensive and performative aspects (Berente et al., 2016) by enacting routine actions themselves (e.g. automation) and/or by enabling human agents to enact routine actions through artifacts (e.g. human-artifact interaction). Accordingly, artifacts, as physical manifestations of organizational routines, have many forms (e.g. written rules and forms, physical settings, digital media) and virtually endless functions (Pentland & Feldman, 2005). As such, information exchange media and technologies used in the AEC practice (e.g. BIM tools, digital files, and folders) are artifacts that can embody the ostensive aspect of routines or materialize the performative aspect.

4-3-3-1- Conceptualizing Misalignments and Disruption in Organizational Routines

Dynamicity and change in routines can be either adaptive or generative (Berente et al., 2016; Feldman, 2015; Pentland & Feldman, 2005). Adaptive change refers to the ways in which organizations adjust their routines to adapt to changes that are exogenous to the routines. Generative change is endogenous as actors mindfully and gradually introduce change into their routines through reflective assessment, improvising performance, or deviating from existing routine aspects (Abdirad et al., 2020; Becker, 2004; Feldman, 2015). These adaptive or generative mechanisms of changing routines involve the interplay between the ostensive, performative, and artifact aspects of routines. As these routine aspects are mutually constitutive and interdependent, implementing or changing sociotechnical systems can be successful only when these aspects mutually align (Volkoff et al., 2007). This alignment is important for the conformance of organizational processes to logics of practice. In occasions when exogenous changes enforce new logics of practice on socio-technical systems, alignment between the ideas, actions, and mediatory artifacts of routines can become elusive (Berente et al., 2016).

Alignments (or misalignments) may emerge in three pair-wise dimensions involving the three aspects of routines (Berente et al., 2016). First, Ostensive - Artifact alignment (OA) refers to the degree of correspondence between the general idea of a routine and features of artifacts (Berente et al., 2016). Artifacts are aligned to the ostensive aspect of the routines when they are guides or resources for actions, but they do not necessarily determine actual performances (Pentland & Feldman, 2005). OA misalignments (O ╫ A) appear when technical aspects or affordances of artifacts change such that they cannot support the idea of routines; or the idea of routines shifts such that the artifacts could no longer account for or embody them (Berente et al., 2016). Second, Artifact - Performative alignment (AP) is the degree of correspondence between actions and routine artifacts. In the case of AP misalignment (A ╫ P), artifacts lack adequate functionality to support performance or place added burden on actors to carry out tasks. In this case, artifacts may remain stable while the practice shifts to exclude the artifacts (Pentland & Feldman, 2005). Also, actors may fail to incorporate artifacts into their routines in certain contexts. Avoiding routine artifacts, partially using them, or using alternative non-routine artifacts to achieve outcomes could be indications of AP misalignment (Berente et al., 2016). Third, Performative - Ostensive alignment (PO) is the degree of correspondence between how actors conceive a routine and what they do to achieve the intended outcomes. Deviating from the idea of a routine is a sign of PO misalignment (P ╫ O) and can undermine stability of routines. When these deviations persist, there is a need for revisiting the idea of routines or establishing performance control measures to ensure conformance (Berente et al., 2016).

This review of literature informed this paper to conceptualize disruption of routines as occasions in which external forces demand new ideas, artifacts or processes that cause misalignments in routines. Misalignments come to the fore as technical breakdown, conflicting standards, or even deeper clashes between practice logics (Berente et al., 2016; Smets, Jarzabkowski, et al., 2015). These disruptive circumstances trigger adaptation mechanisms or organizational responses that bring about new alignments, or in reverse, additional drift-away from the original practice logics and existing routines (Abdirad et al., 2020; Berente et al., 2016).

4-3-4- Organizational Responses to Competing Practice Logics

The organization theory has long evidenced the concept of dividing or detaching elements of organizational practice as a mechanism of separating competing or incompatible logics (Smets, Jarzabkowski, et al., 2015). This concept has emerged in the literature under different constructs such as compartmentalization in institutional theory (Jarzabkowski, Matthiesen, & Van de Ven, 2009), splitting in paradox and strategy theories (Smith & Lewis, 2011), and segmenting in practice theory (Smets, Jarzabkowski, et al., 2015). These constructs address how organizations separate and address incompatible logics in different organizational units to minimize conflicts in their practice (Abdirad et al., 2020; Smets, Jarzabkowski, et al., 2015). Other responses to disruptive forces address the feasibility of melding incompatibilities or managing their interactions. Examples include constructs like blending, selective coupling, and bridging, which are developed in the institutional and practice literature (Smets, Jarzabkowski, et al., 2015). Blending is a mechanism to settle incompatibilities into piecemeal sets of expectations (hybrid logics). Selective coupling is discretizing external forces to rationally manage their interaction without over-privileging any forces. Bridging is more situated and dynamic than other mechanisms as it temporarily combines forces such that addressing one force can inform or facilitate the goals, means, or values of another (Smets, Jarzabkowski, et al., 2015).

Conceptually, these constructs vary in three important dimensions: (1) whether and to what extent they allow forces or logics to interact, (2) whether such interactions are short-term or long-term, and (3) whether these mechanisms are planned structurally by management or addressed in day-to-day work by individuals. Furthermore, they tend to address external forces that are persistent and routine for organizations (Smets, Jarzabkowski, et al., 2015). Therefore, they neglect temporary forces that impact project-oriented organizational practice. AEC projects that experience disruptive information exchange requirements offer a proper context to explore this neglected research territory.

4-3-5- Point of Departure and Research Question

The foregoing review of literature highlighted the knowledge gaps that informed the points of departure for this research. First, little is known about occasions in which AEC firms face a surge of divergent initiatives that concurrently disrupt their information exchange routines across projects. Second, existing research has rarely dealt with project initiatives that overreach project boundaries and disrupt routines at the portfolio and operation levels in firms. Third, with the overreach of disruptive information exchange requirements to higher organizational constellations, the mechanisms through which AEC firms perceive and respond to them are not fully understood. Fourth, organizational responses to temporary and potentially incompatible information exchange requirements have not yet appeared in the literature due to the focus on persistent external forces. To address these gaps, this paper explores how firms perceive and respond to the surge of disparate information exchange initiatives that affect routines at different constellations of their practice.

4-4 - Research Design, Setting, and Methods

4-4-1- Research Design and Context

This study adopts an interpretivist paradigm that relies on the multiplicity of interpretations, discourses, and actions that individuals attach to their experience (Mackay et al., 2001). Interpretivism is a well-established approach to studying context-dependent and complex organizational phenomena (Saunders et al., 2009). This approach is particularly advantageous to the exploration of whether, why, and how elements of practice evolve (Feldman & Orlikowski, 2011). In-depth research into such complexities is often pursued through qualitative methods of inquiry and case-study analyses of natural organizational settings (Langley, 1999).

This study chose the U.S. construction market as the research context. Previous studies on information exchange initiatives identified the U.S. as an innovative but fragmented market in which stakeholders tend to produce disparate information exchange guidelines, protocols, and mandates (Kassem et al., 2015). Furthermore, most firms in the U.S. have short-term project-based relationships with a large set of partners. Consequently, the variability of partners and information exchange agendas across projects makes it difficult for them to align their long-term information exchange practice (Taylor & Levitt, 2007). Therefore, this market is an ideal context within which to explore how organizations perceive and respond to the volatility of custom information exchange initiatives that not only disrupt their routines across projects but potentially overreach project boundaries and impact project portfolios and operations.

4-4-2- Research Setting and Focus

To probe the foregoing question, this study used a descriptive case-study approach (De Vaus, 2001; Yin, 2003). The case presented here was a structural engineering firm in the U.S. with a century-long history of engineering design practice focusing on high-performance structures. This case is a representative of an increasingly common phenomenon in AEC practice in the U.S., i.e. firms concurrently working with disruptive information exchange requirements across projects. Nevertheless, the empirical setting of this case was especially well-suited for exploring this phenomenon because (1) at any given time, this firm had a large portfolio of active projects with a multitude of clients, and (2) it had a variety of highly routinized information development and exchange workflows in its projects, portfolios, and operations to reinforce its digital production and firm-wide efficiency. Therefore, as a unique information-oriented case (Flyvbjerg, 2006), this study can offer new insights on how firms concurrently address varied, competing, and potentially incompatible information exchange requirements across their projects.

This firm, hereinafter called the “Engineering Design Innovators” (EDI; a pseudonym), had over 200 staff members working in a strong matrix organizational structure (PMI, 2017). On the functional side, this structure included specialty engineering market sectors (e.g. Aviation, Cultural, Housing and Hospitality), the BIM department, the IT department, and administration. On the project front lines, each market sector hosted multiple engineering groups. Each engineering group worked on a multitude of projects, for each a project manager assembled a team of engineers and BIM specialists (by placing request to the BIM department). Accordingly, with membership to multiple engineering teams within a group, most staff concurrently worked on a multitude of projects. Although project teams favored having continuity and consistency in staffing, project managers occasionally requested/assigned staff from/to other teams, groups, or markets depending on a variety of factors such as staffing needs, workload, and skill sets.

Over the years, EDI has been an early adopter of different CAD and BIM platforms that became mainstream for digital production and project information exchange in the industry. This firm had established and continuously maintained a variety of BIM implementation routines that involved different constellations of its practice (e.g. projects, portfolios, and operations), and thereby different organizational roles and responsibilities. For instance, the *BIM Manager* oversaw the overall interface between digital technologies, people, and processes while implementing technology deployment routines at the operational level. The *BIM Technical Lead* documented and maintained standard operating procedures that guided project teams in their daily BIM workflows, thus implementing training and standardization routines at the portfolio level. The *BIM Specialists* (some taking the *Project BIM Lead* role) carried out day-to-day project work, implementing information development and exchange routines in their projects. These information development and exchange routines involved a variety of ideas, artifacts, and processes that addressed creating, accessing, organizing, and maintaining heterogonous project information especially digital building information models (for simplicity, hereinafter referred to as “models”). These models aggregated geometric and semantic data for design and construction of building structures with the goal to produce primary information exchange media for a variety of BIM uses such as design and engineering documentation (drawings), coordination (3D models), quantity take-off (quantity tables), and visualization (animations and renderings).

With this network of BIM implementation routines, EDI implemented BIM in all projects even if clients did not specifically request it. For instance, some clients expected only 2D drawing files as project submittals while other clients demanded recurring BIM exchanges in their projects for improved 3D coordination. However, working concurrently on diverse projects with different clients, project teams increasingly faced custom information exchange requirements that enforced diverging BIM initiatives on projects. Although BIM specialists often unilaterally absorbed the disruptive impact of such requirements, there were cases in which information exchange initiatives significantly disrupted routines implemented in projects, portfolios, and operations.

To explore and present salient cases, this paper focused on a multitude of custom project initiatives that required Cloud-based Work-Sharing (CBWS) for model development and exchange. CBWS is a commercial service that can be coupled with conventional BIM tools to store, maintain, and share models on cloud servers (collaborative model development among staff or other contractual parties). Therefore, this service can potentially exclude serialized model transmittals and fragmented information exchanges, thereby enhancing information integration among project parties. The CBWS services that different clients enforced on projects were all consistent in that the same CBWS developer and vendor introduced them into the market. However, the built-in and evolving features of the CBWS artifacts and service, further complicated by custom and inconsistent CBWS requirements across projects, significantly undermined information exchange routines. This research used three sub-units of analysis in this case, including projects, portfolios, and operations, to explore how these CBWS initiatives disrupted routines at different organizational constellations, and how practice participants in each constellation perceived and responded to these disruptions. The author prepared a case-study protocol to address the validity, reliability, and replicability criteria for case-study research (Given, 2008; Yin, 2003). The following sections present some details of the case-study protocol.

4-4-3- Ethnographic Fieldwork and Data Collection Methods

The author conducted a two-year long ethnographic study in the field with a full-time role ranging from a "complete participant" to a "participant-as-observer" (Gold, 1958). Although the author, like other staff, actively took part in building design projects for information development and exchange, only a few senior managers knew about the research aspects of this participatory role. This arrangement kept the work setting, interactions, and activities as natural as possible. It also allowed the author to build and establish trust with the managers and staff over time while keeping the research perspective alive through discussions about enactment or disruption of information exchange routines (Kawulich, 2005). For data collection, the author applied field observation, informant interviews, and artifact analysis to triangulate different data collection methods, data sources, and data types to ensure internal validity (Given, 2008; Yin, 2003). The following sections discuss the details of data collections methods.

4-4-3-1- Field Observation

The author immersed himself in the field to capture the full scope of practice in the case in a natural setting (Yin, 2003). This immersion entailed (1) taking part in at least two dozens of multi-party building design projects as a Project BIM Lead, (2) participating in relevant project and company meetings (e.g. monthly BIM department meetings, BIM management meetings), and (3) watching and tracking actions and interactions that addressed enacting, maintaining, or revisiting information exchange routines in the firm. Through this field observation, the author documented the context and routines of practice as well as situated CBWS idiosyncrasies through recordings, field notes, and artifacts. This form of immersion in everyday work is closely associated with practice research as it facilitates capturing the reality of work as well as ongoing negotiations, interpretations, and understandings of practitioners (Orlikowski, 2007).

4-4-3-2- Informant Interviews

The interviews enabled this research to supplement reflective conversations in the field with data on processes, interactions, decisions, or thoughts that were not readily observable by the author. As a practice participant for two years, the author had extensive interactions with staff at different organizational settings; thus, the author had a detailed understanding of their roles and experience in the firm during the data collection process. Accordingly, the author identified the interviewees in a number of ways: (1) interactions with coworkers in project teams, (2) making direct inquiries to staff from other teams, (3) observing meetings, and (4) snow-ball sampling, with which some critical interviewees such as the BIM manager and Project BIM Leads suggested other potential interviewees to ensure capturing a variety of experiences from different teams and projects. The selected interviewees included the BIM Manager, BIM Technical Lead, Project BIM Leads (13 individuals), and project managers (2 individuals), and project engineers (5 individuals).

These individuals had between 3 to 29 years of experience working in the firm, and 5 to 35 years of experience working in the industry. During the fieldwork, natural opportunities emerged to interview staff. Therefore, the interviewees were considered more of informants rather than respondents during the data collection process (Yin, 2003). As a practice participant, the author carried out frequent but informal interviews without applying a strictly structured interview protocol. These casual interviews first invited informants to identify and reflect on the information exchange idiosyncrasies in CBWS projects. The follow-up interviews became more focused to (1) verify field observations, (2) probe informant about further details about occurrences of CBWS idiosyncrasies, and (3) check the author's emergent understanding of the variations in disruptive CBWS experiences and relevant organizational responses. The questions applied (1) the critical incident technique (Flanagan, 1954) and (2) the time-line interviewing technique to capture concrete examples and extreme cases as they developed through time (Dervin & Frenette, 2001).

4-4-3-3- Artifact Analysis

For artifact analysis, the author collected data from digital or physical artifacts from the intranet knowledge repository, standard operation procedures (e.g. articles, guidelines, standards, and reports), digital tools (e.g. software, hardware, and digital repositories used in the projects), internal meetings (e.g. meeting minutes and presentations), and project information and communications (e.g. emails exchanges, models and drawing submittals, project internal memos). This analysis provided a rich context for triangulation of observations and interviews that concerned organizational routines and their alignment or misalignment with situated CBWS requirements. These artifacts also facilitated bringing contextual sensitivity to data collection as the analytical power and value of artifacts depended on their association with different organizational settings (projects, portfolios, and operations).

4-4-4- Data Analysis

The data analysis in this paper applied theory building methods that are commonly associated with case-study analysis and grounded theory traditions (Bryant & Charmaz, 2010). By adopting a practice perspective (Feldman & Orlikowski, 2011) with an interpretivist stance (Mackay et al., 2001), the data analysis treated all qualitative data as proxies for experience (Ryan and Bernard, 2000). The longitudinal nature of this research required a constant comparison between data, theoretical interests, and the existing literature (Berente et al., 2016) to account for the temporary nature of projects and the longevity of higher organizational constellations. The analysis therefore involved iterative coding with sequential but partially overlapping steps for theory building.

Using the routine dynamics as the primary theoretical lens and disruption of routines as the phenomenon of interest, the term "misalignment" from the studies of organizations and technologies piqued the analytical curiosity of this research and guided the analysis (Berente et al., 2016). Accordingly, the first step of analysis focused on (a) marking data points that signified idiosyncrasies in information exchange processes and (2) organizing data points into general themes. In this step, the author identified themes such as "finding model", "accessing model", and "manipulating model" from the first-order findings and subsequently framed and organized indications of routines or routine misalignments around these themes.

In the second step, the author developed a thick description for each theme to bring contextual sensitivity to the analysis of routines and misalignments. More specifically, this step involved creating chronological narratives of critical incidents for timeline sensitivity (Bernard, 2006; Lamont & White, 2005) and untangling roles, responsibilities, and processes for constellational sensitivity (i.e., project, portfolio, operation). This step spotlighted critical findings that showed the disruptive impact of CBWS protocols was not limited to the setting and timeline of individual projects. Examples included issues of finding or accessing CBWS models even after their projects closed out (a concern for information integration in portfolios and operations). With this contextual sensitivity, the author generated a multitude of chronological narratives divided based on the organizational constellations and the ideas of routines. For example, the idea of finding and accessing project models occurred both within projects and across projects, thereby highlighting the contextual significance of routines.

The third step of data analysis involved using descriptive and *in vivo* coding on the data to identify and combine themes emerging from the actions taken to address misalignments and the viability of those actions in different contexts. For example, themes such as "added burden," "new added artifacts," "management," and "ad hoc" were created and documented in analytic memos to explain the empirical, structural, and temporal nature of organizational responses to misalignments.

In the fourth step, the author revisited the memos in tandem with various theories in the organization and AEC literature to find relevant theoretical threads. Accordingly, the author iteratively applied the constant comparison and systematic combining methods to promote the themes into more abstract concepts and orient them within the existing literature (Dubois and Gadde, 2002b; Kelle, 2010). For example, using the concept of "digital information integration" from the AEC literature, the author realized that some routines directly addressed the issues of finding, accessing, sharing, and controlling information as the core concepts in information integration. The author noted that although some custom CBWS requirement promoted temporary information integration among project parties in individual projects, they significantly undermined information integration among projects and staff within the firm as they could not find, access, share, and control models as directly and openly as they used to do. To understand how practitioners responded to this phenomenon, this research synthesized different constructs from the institutional, organization, and practice literature into two broad categories of "separation" and "melding." Separation involves addressing misalignments and competing logics (e.g. custom requirements vs routine practice) in different organizational units to minimize conflicts. Melding involves managing the interaction of competing logics in the same organizational unit when separating them is infeasible or when the advantages of melding outweigh the advantages of separation (Smets, Jarzabkowski, et al., 2015). By adding contextual sensitivity to these constructs, this research analyzed the viability of the separation or melding mechanisms to understand their temporal dimensions. With this analysis, this paper discovered the overarching concept of genericity-complexity trade off in information exchange routines. Generic routines offer generalized dispositions, artifacts, and workflows for practice which give actors the discretion to address misalignments in temporary projects. Complex routines tend to add complementary ideas, artifacts, and processes to existing routines to structurally reconcile misalignments.

4-5 - Findings

Over the two-year study period, the number of projects that required CBWS and the number of staff who worked on CBWS projects significantly increased (from ~5% of project staff in 2018, to ~%15 in 2019, and ~40% in 2020). With this trend, CBWS artifacts and workflows became an important part of information exchange practice in the firm. These new artifacts and workflows caused misalignments in information exchange routines from the early implementations. The misalignments emerged in how the features in the CBWS artifacts, further complicated by custom requirements, undermined the ostensive ideas and routine workflows that were entangled with the existing artifacts. For instance, the fundamental ostensive idea of information exchange in the firm was that every staff should have access to all information in every project. This idea was to support the matrix organizational structure, wherein staff concurrently took part in multiple projects. The routine artifacts implemented to support this idea were a local network of shared drives (LNSD) and a standard framework for organizing and naming project folders and files. The CBWS requirements demanded implementing new artifacts and sharing and maintaining models on the cloud (instead of the LNSD) to support real-time model exchanges with external parties. However, the misalignments that these requirements brought about were not merely a change in the location of models. The findings showed that custom CBWS requirements caused a multitude of misalignments in information exchange routines. This section organizes findings around these misalignments in six vignettes categorized under two broader themes: (1) Emergent Misalignments in Project Information Exchange, and (2) Emergent Misalignments in Project Portfolios and Operations. Each vignette addresses a thread of organizational routines and relevant misalignments by uncovering the associated ideas, artifacts, and processes. Furthermore, each vignette summarizes the variation of divergent custom requirements across projects and the mechanisms through which practitioner responded to the emergent disruptions. In the following narratives, misalignments between the ostensive (O), artifact (A) and performative (P) aspects of routines are marked with ╫.

4-5-1- Emergent Misalignments in Project Information Exchange

4-5-1-1- Where is the Project Model?

Before CBWS implementation, the LNSD was the single primary location for storing and using all documentation, models, and other analysis or reference files (e.g. spreadsheets, sketches, drawings) for every project. As an exogenous change to the routine artifacts, the CBWS requirements demanded uploading project models to the cloud. Nevertheless, other project files and documentation had to remain on the LNSD. The reasons included that not all projects required

CBWS; there was no expectation of sharing miscellaneous files and documentation with other parties; and CBWS did not support storing every file format.

This change in the location of models (from the LNSD to CBWS) caused misalignments in routines and engendered internal disintegration of information. The foremost disruptive impact of moving models to the cloud appeared when staff could not find and use the primary models per their existing dispositions. The CBWS did not support the idea that "all information is stored in the same location" (O ╫ A). Furthermore, finding CBWS models within the cloud added much burden to routine workflows aimed at finding project models (A ╫ P). In a routine scenario, knowing project names sufficed for finding and accessing models in the LNSD. For CBWS projects, however, the staff needed information like names of clients, hubs, CBWS services, and the version of the BIM platforms to find project models. Since there was no a priori arrangement for communicating or documenting this information, each project team experienced such disintegration of information in a different way. In significant cases, instead of finding the models on the hubs, staff mistakenly worked on older models that had remained on the LNSD even after transitions to CBWS, thereby causing duplicate or lost work on projects. Other disruptive cases involved staff's inability to find any information about the location of project models. Furthermore, with frequent developments in CBWS services, the software vendor added new interfaces and methods for using cloud models (e.g. web browser, virtual drive application, BIM tool interfaces). Some of these methods provided users with access to the milestone models, while other methods provided users with access to the latest live models. The following excerpt from staff conversations illustrates the growing uncertainties among staff about their inability and the added burden to find project models:

Project Engineer: "I was looking at the Floor 43 in the model, but I don't think that was the latest version as seen on the 25% Design Development PDF sheet."

Project BIM Lead #10: "Are you viewing the model through a web browser [which shows the milestone snapshot version]?"

Project Engineer: "No, I went into the [BIM Tool] and tried to open the model from the CBWS Virtual Drive; still not seeing the updates, maybe I am doing something wrong here…"

Project BIM Lead #10: "You should access it through the [BIM Tool] but do not open it from the CBWS Virtual Drive [which also shows milestone snapshot version]. If you wait several seconds after opening the tool, it will list the CBWS folders and primary models on the left side. You can access the live model over there." (from Project C)

With the increased number of CBWS projects and different approaches to share the knowledge of cloud models, the staff felt the need for consistency in communicating CBWS information. The recurring disruptive experiences and lessons learned from multiple CBWS projects triggered new and more durable adaptation mechanisms. These adaptation mechanisms gradually added extra components to the existing routines. For example, staff absorbed the ostensive idea of CBWS workflows in their daily conversations. The question of "is that a CBWS project?" increasingly became a part of daily staff communications when BIM implementation was discussed. The management developed new routines to reconcile the disintegration of project information in the artifacts. For instance, the management adjusted the existing procedures for organizing and naming folders and files in the LNSD such that the routine artifacts themselves hinted at the location of CBWS models:

"If you have a model that is residing on CBWS service, please place the attached .txt file [named THIS PROJECT USES CBWS TO HOST THE BIM MODEL.TXT] into the BIM folder for your project on the LNSD. This will hopefully help avoid any confusion if someone goes looking for a model and finds something with an old date, or no model at all. Ideally, we are all communicating within project teams and with those who are just temporarily helping out where the model lives. This file will serve as a backup should no one be available to explain until we can come up with a better method." (BIM Technical Lead—Email to Staff)

Despite making existing routines more complex by incorporating these new ideas, tasks, and artifacts to existing routines, these extra components sustained internal information integration at EDI by reconciling the inconsistencies across project artifacts and processes. The foregoing descriptor also reveals the emergent nature of misalignments and the added burden associated with the solutions as staff strived for even more effective responses.

4-5-1-2- Who Can Access the Project Hub?

In CBWS workflows, clients as hub managers registered and invited other project parties to the CBWS service (using an email address for each user). Based on the level of permission set by hub managers, users could upload, view, or change models shared on the cloud. With the external management and control over permissions, project teams at EDI lost the real-time control over how many and which staff could access CBWS models. Disruptions appeared when turnover in staffing and fluctuations in workloads forced project teams to place requests for registering new users to hubs. Such experiences disrupted the commonly held disposition at EDI about having unrestricted access to every project model (O ╫ A). They also added administrative burden to routine workflows when staff had to request access to project information (A ╫ P). Different approaches that clients took toward these requests further disintegrated internal processing of project information at EDI. For example, some clients pushed back against the frequent requests to register users to hubs, thus limiting internal access to project information. For some clients, accommodating such requests was bureaucratically time-consuming and caused delays in information access and exchange. These circumstances showed that addressing this misalignment in routines often needed idiosyncratic responses from project teams. The recurrent disruptions and lessons learned overtime provoked new adaptation mechanisms to minimize requests for registering new users. For example, some project teams shared CBWS credentials among staff to facilitate their access to hubs. In some projects, teams sent a lengthy list of potential staff to clients to register to hubs to grant access to as many staff as possible at the kickoff milestone. As illustrated in the following descriptors from two different projects, these responses gave rise to new genres of ad hoc internal and external communications:

"As we're preparing to allocate more resources for future work. Kindly add the following members to our CBWS team [followed by a list of emails]." (Project BIM Lead Email to Client—Submitting a List of Potential Users in Project A)

"When you receive the CBWS email invitation for the project Medical Center, please accept it to join the team. There is no immediate need for you to do anything for this project. We are being proactive about enabling access for staff that have CBWS licenses in case there is a need for additional members to join the team in the future." (Project Manager—Email to Staff—Submitting a List of Potential Users in Project A)

"This is a [version] 2019 CBWS project. You will have to use a CBWS account. I will let you know what the project name, file name, and folder are. I'm also asking John what

username/password is available for you to use." (BIM specialist #15 to BIM specialist #10 -Observation of Communications—Sharing CBWS credentials in Project B)

In response to these diverging solutions, the management created new workflows to minimize additional requests for registering staff to CBWS hubs. For instance, the BIM department created a new procedure for the initial registration process, which entailed submitting several anonymous email accounts to clients at the project kickoff milestones to allow access for temporary or future project staff:

"When supplying our clients with your list of staff to access CBWS hubs please include these 'dummy' accounts [CBWS_USER_1, CBWS_USER_2, CBWS_USER_3, etc.] to make it easier to manage project staff access" (BIM Manager – Email to Staff)

This workaround alleviated disruptions to information access and integration by melding the CBWS and LNSD logics (generic access for everyone) and adding new ideas, tasks, and artifacts to existing routines. However, disparate requirements in projects continued to undermine these routines and restrict internal information integration. For example, some clients resisted the idea of registering anonymous email accounts. Some clients went as far as creating new email addresses and purchasing CBWS subscriptions for project teams to micro-manage access to hubs. These experiences highlighted the recurrence of occasions in which highly custom project requirements disrupted the enactment of routines and necessitated project-specific ad hoc responses.

4-5-1-3- Who Is Driving My Model?

The routine workflow for multi-party model exchanges at EDI involved sending copies of project models (e.g. via email) to other parties because only internal staff had access to the LNSD. In contrary to this routine workflow, in every CBWS project, clients as hub administrators (and other parties who received relevant permissions from clients) had full access to read from and write to all primary project models hosted on the cloud. Consequently, they could move, open, or change EDI's models anytime rather than just viewing or working on copies:

"This is a new paradigm to expose our work-in-progress models to other project parties. There is always the risk that they might change something in our models." (Project BIM Lead #1)

This feature in cloud services violated the ostensive idea that "primary project models are maintained internally, shielded from external access" (O ╫ A). Further misalignments appeared in routines when the changes that other parties made to project models added burden on staff to recognize or reverse the changes (A ╫ P). For instance, some clients opened EDI's models, edited model components or data, and locked the edited model components. In some projects, clients upgraded models to a newer version without notice (e.g. upgrading a 2018-version model to a 2019-version model), which caused a series of errors, warnings, and missing components in project models. Besides making potentially unwanted changes to project information, accessing and locking project models by external parties restricted EDI's ability to carry out project work. Although the magnitude of such disruptions varied across projects, all disruptions caused ad hoc troubleshooting attempts among parties to track issues, fix models, and restore access for project staff. The following descriptor portray one of such experiences:

"I did a bunch of edits to the model but upon saving, it said someone else with an unfamiliar username had the ownership of model elements. We got on the phone with the client and found the person. We walked him through the steps to relinquish our model and the edited components. They wanted to add data parameters to our structural components,

but they did not synchronize the model properly… it took us a day to get it sorted out." (BIM Specialist #2—Project D - Interview)

As a structural response, the BIM department set up a new procedure wherein project teams informed the management if any of awarded projects implemented CBWS. The goal was to pro-actively coordinate with clients in how they set up folders, files, and permissions and work with models to minimize disruptions:

> *"I have asked project managers to email me when a project requests the use of CBWS collaborative modeling so we can have a CBWS kick-off meeting. We have seen different ways that clients set up folder structures and permissions which might allow outside firms misuse our models. We have had such experiences and can offer some suggestions to teams." (BIM Manager - Interview)*

This addition to internal routines aimed to support external information integration among project parties while preventing disruptions to internal information integration. However, some clients still mandated their preferred CBWS workflows, which occasionally led to the recurrence of misusing project models.

4-5-2- Emergent Misalignments in Project Portfolios and Operations

4-5-2-1- How Can I Extract This Detail from That Project?

As discussed in the foregoing section, the routine to provide every staff with access to information from all projects was beneficial to individual projects for swift project staffing and information exchange. Outside the boundaries of individual projects, this routine enabled staff to extract digital building assemblies and details from models and re-use them in other projects and in the digital knowledge repository. Therefore, from a project portfolio and operations points of view, EDI relied on the idea that "every staff can access all project files" to share technical knowledge across projects and avoid duplicate work and many hours spent on recreating similar information. Therefore, the misalignments in finding and accessing information using CBWS workflows were not bounded to the setting and timeline of those CBWS projects. Accordingly, both the idea of having open access to a known spot for project information (O ╫ A) and the actions that staff enacted to exploit existing information were disrupted (A ╫ P):

> *"This truss detail is from Project Z. It is a CBWS project. I want to change the detail a little to fit the depth of truss in this Project Y. Pete was the BIM lead on the Project Z; you can get in touch with him to see how you can insert this detail from that model so you do not draw it all from scratch." (Project Engineer—Observation of Conversations—Project Z)*

Depending on the ease and timeliness of access to the sought-after models, staff chose to either recreate information or coordinate with others (e.g. the management or project team-members) to find the CBWS models. Therefore, in such cases, situational exigencies drove the response mechanisms of practitioners as they had to weigh between potentially competing logics. In sum, by constraining access and distributing projects into fragmented hubs, custom CBWS protocols disrupted knowledge sharing and information integration at the project portfolio level.

4-5-2-2- Which CBWS Scenario Is This?

With the increasing number of CBWS projects at EDI, not only CBWS workflows deviated from the routine practice at EDI, these workflows themselves varied in how clients required and implemented the growing number of CBWS features. For instance, in some projects, all parties could view a real-time state of models in their BIM platform as each party changed, explored, or documented their design ideas (i.e. seeing frequent changes in live models). In some projects, the clients implemented a controlled work-sharing feature (with version/change tracking) to allow parties to publish their updated models or view updated models from other parties through their BIM platform only when they chose to do so. In some other projects, clients implemented a more limited and older application of CBWS, wherein they used the cloud service merely as a typical online storage to upload/download models manually.

Besides being disruptive initiatives in individual projects, these incompatible variation of CBWS workflows hindered setting up relevant training programs at the operation level in the firm. As an operational routine, the baseline training programs for staff used the LNSD as the primary artifact that supported information exchange workflows. The many variations in the service and often temporary custom protocols of implementing CBWS in individual projects challenged the ostensive idea of "having the same baseline information exchange training for all staff" (O ╫ A):

> *"[The Software Developer] is utilizing a two week development cycle for the [CBWS] service which brings additional features to projects quickly but requires a nimble and vigilant response by us to vet features and capabilities as appropriate for the project teams." (BIM Technical Lead—Email to Staff)*

> *"So far, I have seen at least seven [CBWS] scenarios that mix and match CBWS features and most of them are less than ideal for us from the internal production and efficiency standpoints. We deal with them on specific projects, but we cannot set up a standard operating procedure or all-staff training for every random scenario." (BIM Manager - Interview)*

These inconsistencies in the artifacts and workflows engendered misalignments in the idea and performance of training routines at EDI. Because of the variations and incompatibility of the custom CBWS workflows, the management experienced the added burden to offer ad hoc training and support to specific project teams (A ╫ P). Consequently, the knowledge and implementation of CBWS artifacts and processes became varied and unbalanced among project teams and staff, making the overall information exchange practice at EDI less integrated over time.

4-5-2-3- When Should We Deploy New Software Updates?

At the portfolio and operation levels, parts of BIM management routines involved planning the deployment of digital tools, managing software subscriptions, and coordinating and scheduling deployment with the IT department. These tasks addressed installing or updating software according to exogenous client demands and internal needs for information development and exchange (e.g. which software, how many users, when to use, for how long, etc.). These needs and demands came to the fore when vendors released new deployment packages for BIM applications (e.g. versions, updates, and patch fixes), or only in rare circumstances, when individual projects raised their highly unique technological requirements. Therefore, looked at ostensively, tool management at EDI presumed a unified planning and deployment approach for all projects and computing resources. The misalignments in this routine appeared when the roll-out of CBWS workflows prompted a surge of unique technological requirements and requests; this not only disrupted the idea of having a consistent tool management approach (O ╫ A), but also put additional burden on the management to address idiosyncrasies in individual projects (A ╫ P). For instance, CBWS required a per-user subscription (with added cost) on top of the routine per-group subscription for the pool of BIM licenses. This added another layer of complexity to the subscription management routines because not all projects used or needed CBWS subscription, but staff turnover and new projects required reassignment of licenses to those who worked on CBWS projects. With a large portfolio of multi-year projects, it was challenging to predict the CBWS workload, estimate the need for CBWS licenses, and schedule the reassignment of licenses to different users:

> *"All, could you please send me the following project information if you are BIM lead on a project in CBWS? Project Name, BIM Platform Version, CBWS Service Type, BIM Lead Person, Project Manager, Engineering Team, BIM Staff on project, Engineering Staff on project, CBWS Website Address. I need to compile complete staffing information on CBWS projects so I can coordinate BIM software updates and other CBWS related functions." (BIM Manager—Email to Staff—Oct 2018)*

> *"I am auditing our CBWS license usage. We have been maxed-out for a little while, so I want to verify if you are using CBWS actively. Please let me know if you are not using it or using it infrequently so we can have more licenses available." (BIM Manager - Email to Staff—Jan 2020)*

> *"We can assign or release a [CBWS license] user at any time but it is not instantaneous so care must be taken to manage user access [to CBWS projects]." (BIM Technical Lead - Interview)*

Furthermore, custom CBWS scenarios for some clients imposed incompatible demands on the software needed for CBWS. For example, in each CBWS project, all project parties must have the same software version, patch fixes, and updates for the main BIM platform to have consistent model-sharing data protocols. However, different clients had different demands and timelines for updating their software. Thus, staff who concurrently worked on two or more of these projects could not work on all CBWS models because of the limitation to have incompatible software versions, fixes, and updates of the same platform on a computer. BIM management had to address these incompatible requirements using out-of-routine ad hoc decisions. For instance, in some cases, the BIM manager held off on updating the software until most clients updated theirs to the same deployment package. This, in turn, affected the timeline of accessing project files for some project staff when their clients requested software updates much earlier than most clients. In other cases, the BIM manager had to single out specific users or computers to address their unique software needs differently from the rest of project staff or computers in the firm. Therefore, from a portfolio point of view, the incompatible CBWS requirements across projects constrained the management on scheduling and sharing human resources and computing resources among multiple projects. Consequently, the management had to divide tool management tasks for a subset of projects to address their situational exigencies in an ad hoc manner.

4-6 - Discussions

4-6-1- Unpacking Organizational Responses to Disruptive Misalignments

The findings showed that custom CBWS requirements imposed a multitude of ideas, artifacts, and workflows on projects and disrupted one or more of the existing routines in the firm (e.g., finding and storing information, accessing models, controlling models, and tool deployment). With the varying requirements and divergent CBWS implementations across projects, the degrees to which these requirements disrupted existing logics of practice varied too. In the same vein, the mini-cases evidenced a variation of response mechanisms to emergent misalignments in project information exchange routines, ranging from the complete separation of new and existing logics to melding them (see Table 5).

Table 5 – Illustrative Example of Mechanisms to Respond to Emergent Misalignments

Emergent Misalignments	Illustrative Example of Response Mechanisms	
	Melding Existing and New Logics	Separating Existing and New Logics
Finding Project information	New artifacts were added to the LNSD to hint at the location of CBWS models.	No information about CBWS models was stored in the LNSD.
Requesting Access to Models	Registering shared anonymous user accounts to hubs so every staff could access project models.	Singling out projects that restricted access to models to specific staff.
Control Over Model Contents	Pro-actively coordinate with clients to secure project folders and files from external misuse.	Allocated additional time and resources to projects that expose project models to external parties.

The disruptive impact of information exchange requirements overreached project boundaries when two or more projects imposed incompatible demands or logics on the routines of more permanent organizational constellations (operations and portfolio routines). With these incompatible dualities, the staff enacted separation mechanisms to address them in different organizational entities. Examples included (1) re-creating similar information in different projects due to the emergent information sharing issues, (2) developing different training programs specific to a subset of projects due to custom CBWS scenarios, and (3) separating the timelines for software deployment or dividing human and computing resources due to incompatible technological and scheduling demands across projects.

These observations comport with the findings of previous research in that working on disruptive requirements, further challenged by selection pressure in projects, can drive project parties to make swift decisions that temporarily shift the logics of their practice (Abdirad et al., 2020). As discussed in following sections, such requirements and follow-on responses can impact the fundamental aspects of information exchange in firms and undermine internal information integrations.

4-6-2- Perceiving the Shifted Loci of Information Integration

AEC research and practice have been at the forefront of information integration advocacy to improve multi-party information development and exchange in projects. This idea entails sharing information among project parties and consolidating project information from separate technologies, tools, and processes (Kang et al., 2012). This case-study found that custom CBWS protocols in each project aimed at enhancing information integration among network participants by (1) moving project models to shared hubs on the cloud, (2) establishing controlled access to the hubs, and (3) offering the primary sources of project information to all parties on demand. At the same time, however, these exogenous protocols undermined the routines that reinforced internal information integration in the firm. More specifically, (1) the siloed cloud locations for hosting project models, (2) the external management of permissions to access models, and (3) the potential misuse of primary models by other parties restricted project staff from having direct, open, and uninterrupted access and control over models. Based on this evidence, this paper proposes that although custom requirements promote information integration on a project-basis, they can disrupt information integration mechanisms internal to each firm. This issue becomes especially disruptive when a firm tends to share their routine ideas, artifacts, staff, and processes concurrently in multiple projects while disparate and incompatible information integration agendas across projects undermine their mutually constitutive relationships. The findings additionally revealed occasions in which custom project initiatives overreached project boundaries and disrupted routines at the portfolio and operations levels. In the case-study, the variability and incompatibility of custom CBWS protocols enforced competing demands on the knowledge sharing, training development, and tool management routines. These routines tended to invariably support information exchange workflows beyond the specificity of individual projects. The CBWS projects, however, imposed a multitude of exceptions onto these routines, thereby forcing the staff to address the exceptions with impromptu solutions for outlier projects.

These findings empirically establish that custom information exchange initiatives are driving momenta that can pressure practitioners to shift the loci of information integration from their more permanent practice at firms to temporary workflows in project networks. This observation resonates with the literature highlighting the conflicting agendas that staff experience in balancing their temporary alliance to projects and their more permanent obligations to their firm (Dossick & Neff, 2010). These results are also consistent with other research which claimed that BIM implementation is often unevenly distributed in each firm due to project specifities (Kam, 2014). However, this study highlights that the new generation of information exchange initiatives can further entrench the uneven distribution of BIM practice in organizations by undermining the web of shared ideas, artifacts, and processes that reinforce information integration within a firm. By offering situational and organizational sensitivity to the concept of information integration, this paper cautions research and practice on those exogenous information integration agendas that not only undermine information exchange routines in projects, but also restrict firms from sharing, finding, accessing, and controlling information internally among their projects and staff.

4-6-3- Genericity-Complexity Tradeoff in Responding to Disrupted Routines

This study revealed consistent patterns across the vignettes on how project staff and management responded to emergent misalignments in information exchange routines. The initial responses across project teams were highly divergent, highlighting the situated circumstances at the practice level wherein staff themselves had to address project idiosyncrasies. Examples included the temporary and ad hoc approaches to finding and communicating the location of models, registering staff to access hubs, and rectifying the misuse of models by external parties. This evidence resonates with findings from earlier research, which suggested that project responses to disruptive information exchange initiatives can substantially differ from one another and often lack the efficacy and durability to contribute to re-alignments or refinements in more permanent routines (Abdirad et al., 2020; Gavetti & Levinthal, 2000). The findings suggest that generalized information exchange routines (that addressed finding, accessing, and controlling project models) lacked detailed specifications for idiosyncratic circumstances. Therefore, they allowed practitioners to use their discretion in responding to situated routine misalignments. The follow-up responses by the management offered durable structural solutions to the misalignments only after a series of disruptive experiences and divergent responses from staff across projects. These structural responses added new ideas, artifacts, and performances to existing routines, making them more complex to reconcile the logics of practice in CBWS projects with those of the existing practice. These observations comport with previous research suggesting that the reflective assessment of performances across projects enable practitioners to improve upon their responses and repair their routines (Abdirad et al., 2020; Gavetti & Levinthal, 2000; Kokkonen & Alin, 2016).

Based on the foregoing discussion, this study proposes the concept of genericity-complexity trade-off in information exchange routines. With generic routines, staff held a generalized disposition of information exchange in their practice, which gave them discretion to temporarily address situated exigencies in projects. However, the situated and ad hoc responses to information exchange misalignments often favored temporary information integration in project networks over long-term information integration at the firm. With complex routines, in contrast to the generic routines, the management added complementary ideas, artifacts, and processes to existing organizational routines to structurally reconcile the misalignments. Although these complex routines loaded staff with a multitude of new artifacts and tasks, it helped them restore information integration at the firm. Put differently, both generic and complex routines added burden on the firm to address disruptive information exchange requirements in practice. While generic routines put the burden on project teams to respond to disruptive project circumstances, complex routines systemize, coordinate, and distribute the efforts in organizations to sustain internal information integration (even to those projects and staff who do not actively need them).

By emphasizing the contextual, temporal, and structural effects of responses, the concept of genericity-complexity trade-off in information exchange routines complements the earlier discussion on separation and melding mechanisms to address disruptive circumstances. This concept suggests that melding and separation logics of practice can be enacted with generic routines (ad-hoc responses by project teams) or complex routines (systemized responses by management).

4-7 - Conclusions

Drawing on a two-year ethnographic study of information exchange practices at an engineering firm, this paper offered theoretical propositions that extend the episodic and static insights on how AEC firms perceive and respond to disruptive information exchange requirements. By looking at and beyond projects that implemented custom initiatives, this longitudinal study evidenced how misalignments in the routine ideas, artifacts, and processes for information exchange overreached the setting and timeline of individual projects, thereby affecting portfolios and operations. Accordingly, this paper offers three theoretical insights to research on information exchange in the

AEC industry. First, it showed "separation" and "melding" as two primary mechanisms with which practitioners responded to custom initiatives that disrupted their routines. Second, it spotlighted the shifting loci of information integration in practice as custom initiatives increasingly pressure practitioners to shift the focus of their information integration from their more permanent practice at firms to temporary workflows in projects. Specifically, this paper pinpointed a generation of exogenous information integration agendas that not only undermine routines in projects but also restrict firms from sharing, finding, accessing, and controlling information internally among their projects and staff. Third, this study introduced the concept of genericity-complexity trade-off in information exchange routines. This concept in a broad sense explains that generic routines facilitate addressing information integration issues with ad hoc responses in projects, while complex routines systemize, coordinate, and distribute information integration efforts within and among different projects and organizational constellations.

With these insights, this study carries important contributions to research and implications for practice related to information exchange initiatives. First, it reveals the importance of exploring the impact of custom initiatives on different organizational constellations. Despite being potentially temporary and specific to individual projects, custom initiatives can overreach project boundaries and disrupt routines that support project portfolios and operations. Second, this study adds to the knowledge base on BIM research and practice by discussing the real-world implementation and implications of advancing Cloud-based Work-Sharing (CBWS) technologies. This is especially important because earlier research has focused on the technical advantages of cloud technologies over conventional tools, thereby neglecting their organizational and process implications for AEC firms. Third, this research spotlights the juxtaposition of increased information integration among parties in individual projects and decreased information integration among projects and staff in a firm due to divergent information exchange initiatives across projects. This is an uncharted territory for research as the literature has mostly explored information integration in project networks with an emphasis on initial adoption and adaptation to BIM technologies and workflows. Hence, this study serves as an exploratory research that shed light on the ways the surge of custom project initiatives challenges AEC firms.

Chapter 5 - Concluding Remarks

5-1 - Summary and Discussion of Major Findings

This research set out to study an important emerging phenomenon in the industry, i.e., the unprecedented variation of information exchange requirements that firms face in their practice. The importance of this phenomenon is twofold. First, it undermines existing routines and, by extension, the productive capacities that firms tend to maintain in their practice. Second, it brings about disparate and potentially incompatible information integration agendas across projects, and thereby constrains routinization of information exchange within and among firms. This research explored this phenomenon in three case-studies that unpacked ***how this surge of custom information exchange requirements impact existing routines in firms***, and ***how firms perceive and respond to this phenomenon as they strive for maintaining their information exchange routines.***

The first case-study (Chapter 2) answered the question of *"What types of disruptions do firms experience in working with custom information exchange requirements?"* This case-study found that custom information exchange requirements can be so disruptive that they constrain technological and organizational settings and undermine the scope of work, sequence of actions, and timeline of enacting routines in practice. Examples included requirements that demanded (1) exchanging and working with unconventional information, submittals, and data repositories, and (2) generating and exchanging data outside the routine tasks and timelines for information development. The findings additionally revealed that project parties have a network of varied inter-organizational and intra-organizational routines for information exchange, while custom requirements cannot account for this variability of routines. Consequently, their implementation in project contexts can challenge the assumptions that underpin project requirements and bring about unanticipated disruptions to routines.

To understand organizational responses to such unanticipated disruptions, the second case-study (Chapter 3) offered answers to the question of "how firms perceive, interpret, and act upon disruptive information exchange initiatives in a project?" The study found three reasoning mechanisms and knowledge processes that underpin organizational responses: deductive, inductive, and abductive. With deductive reasoning, project participants relied on the rule-like patterns in their existing routines to ascertain the discrepancies between existing practice and new requirements. Using inductive reasoning, project participants enacted reflective assessment cycles through recurring performances to make evidence-based adjustments to their ground rules for action. Through abductive reasoning, project participants formulated new ground rules for action through cognitive search in their response to the selection pressures. The study concluded that the temporary nature of individual construction projects limits the opportunities of project parties to balance their use of abductive and inductive reasoning mechanisms. Therefore, they are likely to identify and enact solutions that are temporary in nature, highly divergent from existing routines patterns and feedback loops, and therefore, not durable and effective to contribute to refining information exchange routines.

The third case-study (Chapter 4) validated the findings from previous case-studies by evidencing many occasions in which responses to disruption of routines were indeed temporary and divergent. The study also made further contributions by answering the question "How do firms perceive and respond to the surge of disparate information exchange initiatives in a multitude of projects?" By looking at and beyond projects that implemented custom initiatives, this study evidenced that the disruptive impact of information exchange requirements can overreach setting and timeline of individual projects, thereby affecting portfolios and operations. The perception of disruption in these organizational constellations was that custom initiatives increasingly pressured practitioners to shift the focus of their information integration from their more permanent practice at firms to temporary workflows in projects, thereby restricting internal project and staff in sharing, finding, accessing, and controlling information (the shifted loci of information integration from internal to the firm to prioritizing exchanges between project participants). The study revealed that practitioners either separated new and existing logics to address project specificities (thus undermining internal information integration) or they found effective strategies to meld them (thus sustaining internal information integration while addressing project specifities). With the lack of a firm-wide respond to custom information exchange initiatives, project teams internally enacted these melding and separation strategies. However, when repeated in a multitude of projects, the management created structural responses that enacted melding or separation of logics in all projects. Accordingly, the study conceptualized genericity-complexity trade-off in information exchange routines to explain how firms develop routines around the frequent disruptions. Generic routines facilitate addressing information integration issues with ad hoc and temporary responses in projects, while complex routines systemized, coordinated, and distributed information integration efforts within and among different projects and organizational constellations. As a conclusion, the surge of custom information exchange initiatives in projects force firms to either isolate their added burden into individual projects (with ad hoc responses that undermine information integration) or systematically distribute the added burden within the organization (with complex solutions that sustain internal information integration).

5-2 - Contributions to Literature and Implications for Research

The case-studies presented in this research marked a departure from the existing literature on this topic by (1) adopting and extending the theoretical lens of routine dynamics (introducing genericity and complexity in routines), (2) looking at and beyond individual project networks, thereby addressing the impact of custom project initiatives on different organizational constellations from the firm perspective, (3) unpacking the dynamic mechanisms through which firms perceive, interpret, and act upon those information exchange initiatives that disrupt routines, and (4) looking at a multitude of custom information exchange requirements to better spotlight the surge of initiatives that clients impose on firms.

With these contributions, this study emphasizes the importance of exploring the current surge of custom information exchange requirements in the industry. These requirements force firms to navigate a multiplicity of information integration agendas that can disrupt the many ideas, artifacts, and processes (scope, sequence, and timeline) that firms embed into their information exchange routines (inter- or intra-organizational). This study suggests that exploring project networks, though insightful, offers only a partial view of how information exchange initiatives affect different organizational constellations in AEC practice. Therefore, studies of information exchange initiatives should offer complementary insights on their impact on other organizational constellations. Furthermore, this study paved a way for future research on this topic by spotlighting the shifting loci of information integration in organizations. In-depth exploration of this phenomenon is of merit as it has a substantial impact on the efficiency and efficacy of internal information exchange and knowledge sharing within firms. This study also lays the groundwork for future practice research into COBie and BIM cloud-collaboration research as two prominent information exchange initiatives in the industry. Despite the many studies on their technical advances, research is yet to fully understand their organizational implications.

5-3 - Implications for Practice

This study cautions the practitioners that the surge of custom information integration agendas in projects continues to potentially disrupt their inter- and intra-firm information exchange routines. Not only can this trend impact individual project networks, it can have significant impact on internal information integration at different organizational constellations in each firm.

For clients and the so-called demand side of the industry, this study showed that unrealistic assumptions and overly custom requirements can have an unanticipated impact on information exchange routines in organizations, and thereby on the success of their information integration agendas in projects. The disruptive impact of such requirements often imposes added burden or costly coordination on all parties to troubleshoot irregularities. Therefore, the increased customization or development of these requirements must be in tandem with their continuous improvement to dampen their disruptive impact.

Looking beyond individual firms in project networks, buffering project contractual parties from certain disruptive requirements can significantly facilitate adopting and adapting to information exchange initiatives in multi-firm settings. This is especially important when efforts are put forth to primarily coordinate and troubleshoot processes instead of contributing to information development and exchange.

Within firms who tend to maintain generic routines, versatile workers can effectively address custom information exchange requirement with ad hoc responses in projects. With ad hoc information development and exchange, however, firms will also need additional roles and responsibilities that restore information integration among projects and staff. These potentially new roles and responsibilities must mediate between different organizational constellations (e.g. projects, portfolios, and operations) at the technical level to ensure information integration is realized in the constellations of practice in an ongoing basis.

If firms tend to maintain complex routines, they will need systematic efforts to continuously standardize and distribute new information exchange solutions across their organizations. Although this approach sustains information integration in firms, it imposes new artifacts, ideas, and processes, and thereby learning and cognitive loads on all organizational constellations. This suggests that firms need to consider continuous training on information exchange initiatives, skill building workshops, and swift knowledge exchange of ongoing project practices to proactively sustain internal information integration as they address custom requirements across projects. Accordingly, firms will need potentially new management roles or responsibilities that address organizational learning and knowledge management in the contexts of digital project delivery and information integration.

Beside the implications for developing and responding to custom information exchange requirements, this research offered practical insights and lessons learned of implementing two state-of-the-art information exchange initiatives in the industry: COBie and BIM Cloud Collaboration.

5-4 - Limitations

This study offered insights from the construction industry in the United States, and more specifically from the commercial construction sector. Therefore, the findings in this research must be interpreted with caution in terms of the transferability of findings to other regions and market sectors (e.g. residential and industrial). Furthermore, the case-studies presented in this research aimed to make a grounded analytic contribution (De Vaus, 2001). Therefore, there is no claim of statistical generalizations in this research. Given its interpretive stance, despite capturing in-depth findings and making grounded propositions, this research is limited by the intersubjective accounts of the project participants and those of the author (Mackay et al., 2001). For instance, to determine what constitutes a "disruption" or "misalignment" in information exchange routines, this study relied upon and analyzed the accounts and experience of project parties (with interviews, observations, participation, and artifacts). The meaning, experience, and perception of disruptions were embedded into situated project circumstances and context-dependent organizational settings wherein "specific people, for specific reasons, at specific times, in specific places" enacted or altered routine performances (Pentland & Feldman, 2005, p. 802). Therefore, this study acknowledges that the perception and experience of disruptive information exchange initiatives (e.g. the nature, magnitude, and breadth of disruptions) can vary in projects and organizational settings and even among practitioners that have different degrees of experiential overlap in their work on such initiatives.

5-5 - Future Research

This study highlighted a variety of information exchange routines across the case-studies. These routines address the shared ideas, artifacts, and processes that project teams use in their practice. This research made an attempt to identify these shared aspects of routines within and across the firms to analyze how firms respond to disruptions and misalignments of routines. Future research needs to examine these shared ideas, artifacts, and processes more closely in a larger sample of firms and projects to potentially carry out an ontological study of information exchange routines (e.g. what ideas, what artifacts, and what processes). An ontological study can help specifiers, software developers, and practitioners understand the variation of practices that firms establish internally as well as common denominators in practices of the loosely coupled firms in construction markets. This can potentially mitigate the unintended disruptions that custom information exchange initiatives impose on AEC practices and inform practitioners on how best practices develop their routines in different constellations of their practice (e.g. projects, portfolios, and operations).

This research studied routines of builders and designers in different cases. It appears that the organizational structure of firms influences the extent to which they share information exchange ideas, artifacts, and processes across their projects. Future research should focus on determining how different organizational structures (e.g. matrix, functional, satellite) impact information integration in firms and influence organizational responses to disruptive information exchange initiatives. Accordingly, it is important to understand how different organizations restore or sustain internal information integration in their practice when external information integration agendas in projects disrupt their routines.

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