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"MATTER BATTLES": COGNITIVE REPRESENTATIONS, BOUNDARY OBJECTS, AND THE FAILURE OF COLLABORATION IN TWO SMART CITIES

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In this paper, I present a longitudinal study of two *smart city* projects that brought together experts from diverse knowledge domains. Both projects structured collaboration around the development of boundary objects that could integrate actors' expertise. In both projects, however, the objects sparked conflicts that exacerbated rather than attenuated differences. I develop a process model exploring how and why the development of boundary objects can manifest as divisive conflict that derails collaboration. In both projects, extreme novelty gave rise to *concept ambiguity*, a lack of shared ideas about what smart cities were, and *process ambiguity*, a lack of shared ideas about how smart cities should be developed. Ambiguity led actors from diverse domains to form divergent *cognitive representations* about smart cities. As they developed boundary objects, actors made decisions that violated some cognitive representations, while reifying others into material outcomes. Their efforts to develop the objects manifest as *matter battles*: high-stakes conflicts about material outcomes that, over time, set the stage for collaboration failure. In advancing these ideas, I provide an alternative perspective to the literature on collaboration across boundaries, which has primarily treated boundary objects as tools of integration rather than weapons of division.

> "When we launched the project, we were thinking about systemic change.... The apt title for what we just went through is systemic failure."—SmartBlock designer, interview

Innovation often results from collaboration between groups of experts coming together from different knowledge domains. Projects with innovative aims—those seeking to introduce a new product class (Hargadon & Sutton, 1997), tackle an unprecedented social problem (Rashid, Edmondson, & Leonard, 2012), or push forward the frontier of science (Ben-Menahem, Von Krogh, Erden, & Schneider, 2016; Bruns, 2013; Kaplan, Milde, & Cowan, 2017)—benefit from collaboration between experts who recombine their diverse knowledge and capabilities. When they succeed, these projects can produce groundbreaking results: category-defying products (Hargadon & Sutton, 1997), awe-inspiring rescue efforts (Edmondson, 2012), new classes of life-saving drugs (Ben-Menahem et al., 2016). However, the difficulty of collaborating across boundaries can also lead to systemic failure.

The challenges of collaborating across boundaries have been well-documented by the literature. Groups from diverse domains enact distinct norms, practices, and routines that resist change (Edmondson, Bohmer, & Pisano, 2001), and bring occupation-specific identities and logics that promote in-group cohesion and out-group discord (Battilana & Dorado, 2010; DiBenigno, 2018; Glynn, 2000). Diverse experts also see the world in different—and sometimes incompatible—ways (Dougherty, 1992; Leonardi, 2011; Orlikowski & Gash, 1994). They speak distinct languages (Bechky, 2003a, 2003b; Carlile, 2002), and even use the same words to represent separate concepts (Cronin & Weingart, 2007). To innovate, they must traverse or transcend these deep social and cognitive boundaries to build common practices and ideas (Cronin & Weingart, 2007; Majchrzak, More, & Faraj, 2012). This is especially challenging in novel settings, where they lack established models or precedents that can guide their actions and interactions (Faraj & Xiao, 2006).

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Because of the importance, and the difficulty, of collaborating across boundaries, much research has focused on identifying the tools that allow experts to overcome their differences and integrate their knowledge (see Okhuysen & Bechky, 2009, for a review). Scholars have highlighted the importance of *boundary objects*—representations including blueprints, machines, and prototypes—in facilitating collaboration and innovation. Boundary objects provide touchstones that help reveal differences, build common ground, and facilitate knowledge integration (e.g., Bechky, 2003a, 2003b; Carlile, 2002, 2004; Nicolini, Mengis, Swan, 2012; Star & Griesemer, 1989). They can thus help structure and encourage collaboration across a range of settings, including semiconductor manufacturing (Bechky, 2003a, 2003b), new product development (Carlile, 2002; Seidel & O'Mahony, 2014), and scientific research (Nicolini, Mengis, Swan, 2012).

The current study contributes to research on collaboration across boundaries by drawing on two deviant cases (Ragin & Becker, 1992). I studied two large-scale *smart city* projects that brought together groups of experts from diverse knowledge domains who structured collaboration around the development and use of boundary objects. However, despite significant investment, early excitement, and the deployment of these tools of integration, collaboration in both projects failed. Notably, rather than allowing actors to develop shared ideas, boundary objects in both projects sparked heated conflicts, and exacerbated rather than attenuated differences. I draw on extensive ethnographic data from these deviant cases to ask: Why and how can attempts to develop boundary objects—typically conceptualized as tools of integration—manifest as divisive conflicts that derail collaboration?

To answer this question, I consider the interplay between ambiguity and materiality. The groups I studied sought to build two of the world's first smart city developments. Because of the extreme novelty of their context, they faced profound and simultaneous *concept ambiguity* about what smart cities were, and *process ambiguity* about how smart cities should be developed, including who should lead their creation. As the groups began their work, they formed different *cognitive representations*: simplified mental models about smart cities that were shaped by their experiences from the past, and that guided their preferences for the future (Lakoff, 1987; Simon, 1991; Thagard, 1996). In the early phases of each project, these differences were undetected and hence uncorrected. However, when the development of boundary objects occasioned the selection of important project choices, actors' divergent cognitive representations shaped incompatible ideas about the best ways forward. Facing pressure to develop the objects, rather than creating a common perspective, actors made divisive decisions that reified particular cognitive representations while violating others.

I propose that the materiality of each project's outcome—a city that would occupy a permanent physical space, and that could only be built once—imbued this process with heightened significance. Because the end result of each collaboration was a permanent and irreversible outcome—a smart city that would serve as a reference for urban developments of the future—actors felt that there was much at stake in each decision. Thus, their efforts to develop boundary objects manifested as *matter battles* (Boyer, 2011): high-stakes conflicts about material outcomes. Actors responded to matter battles in emotional ways that gave rise to simplified stereotypes about their collaborators. Over time, repeated matter battles set the stage for collaboration failure.

By elaborating this process, I contribute to the literature on collaboration and innovation across boundaries. This study's key insight is that, in settings characterized by diversity of expertise and extreme novelty—including unprecedented collaborations (Edmondson, 2012), and ventures that aim to catalyze new industries (Zuzul & Edmondson, 2017), the very projects that are so often the drivers of systemic change and innovation—the development of boundary objects that occasion the transformation of abstraction into materiality can be deadly to collaboration.

BOUNDARY OBJECTS AS TOOLS OF INTEGRATION

Experts from distinct knowledge domains come from different thought-worlds (Dougherty, 1992). They often unknowingly focus on different critical aspects and development requirements of the same task (Barley, 1986; Edmondson et al., 2001; Leonardi, 2011; Orlikowski & Gash, 1994). Even when these differences are revealed, diverse experts often lack a common language they can draw on to integrate their skills and points of view (Bechky, 2003a, 2003b; Carlile, 2002). As Leonardi (2011) argued, these challenges can leave them akin to the six blind men in the ancient Hindu story, who each touch a different part of an elephant and describe it in different ways, and then (quoting John Godfrey Saxe's famous poem), "rail on in utter ignorance of what each other mean" (367).

Because of the importance of innovating through collaboration, scholars have identified some of the ways that experts from diverse domains can surface their differences and integrate their knowledge. Successful cross-boundary collaboration can depend on the creation of an environment that supports and encourages knowledge sharing. Boundary organizations (O'Mahony & Bechky, 2008) and shared spaces (Kellogg, 2009; Valentine & Edmondson, 2015) can provide arenas where ideas can be articulated and common understandings can be built. Face-to-face meetings, including brainstorming workshops, cross-functional planning meetings, and status update meetings, can allow actors to voice their perspectives, and incorporate them into shared ideas (Levina & Orlikowski, 2009; Majchrzak et al., 2012). Coordination structures including digital technologies (for instance, intranet servers) can support or even substitute for these arrangements by allowing individuals to display and assemble their work in ways that are visible and meaningful to all (Kellogg, Orlikowski, & Yates, 2006).

Collaboration can also be facilitated through the use of specific tools of integration that allow experts to understand and combine their ideas rapidly and *in situ*. Much of the literature on cross-boundary collaboration has highlighted the importance of boundary objects in surfacing differences and encouraging integration. Boundary objects are pragmatic or tangible representations that are relevant to all actors (Bechky, 2003b: 352; Carlile, 2002, 2004; Star & Griesemer, 1989). Successful boundary objects include, among others, drawings or notes, joint papers, PowerPoint slides, blueprints, machines, or prototypes (Bechky, 2003b; Boland, Lyytinen, & Yoo, 2007; Carlile, 2002; Nicolini et al., 2012).

Boundary objects encourage innovation by providing a common referent that actors can point to, work with, and manipulate as they seek to combine their knowledge. Doing so can make their implicit differences concrete, and can allow them to develop nuanced understandings that are difficult to elicit through verbal depictions or descriptions. For instance, Bechky (2003a) found that prototype machines provided boundary objects that could spark concrete discussions about ways to integrate the knowledge of engineers, technicians, and assemblers in a semiconductor manufacturing plant. She described how the boundary objects:

> Allowed people to ground their divergent understandings in the physical world—essentially providing a concrete hook on which to hang their contextual interpretations... [In] many instances...members of the engineering and assembly groups struggled to understand one another in conversation, only to immediately comprehend the other's point when it was expressed with a tangible object that both could place within their respective work contexts. (Bechky, 2003a: 325)

BOUNDARY OBJECTS AS WEAPONS OF CONFLICT

Research has not explored whether and how attempts to develop boundary objects can spark conflicts that impede collaboration. Writing more than 20 years ago, Boland and Tenkasi (1995) theorized that, "boundary objects can, of course, be a center of intense conflict as easily as one of cooperative effort," and that the act of "creating and reshaping boundary objects" can either promote or hinder collaboration (362). Yet most of the literature has focused on the integrative—rather than the divisive—effects of boundary objects.

Recently, some studies have suggested that certain kinds of objects may be insufficient for the successful integration of diverse perspectives (Leonardi, 2011; Metiu & Rothbard, 2013; Seidel & O'Mahony, 2014). For instance, Seidel and O'Mahony (2014) studied six product development teams that used multiple kinds of representations, including stories, metaphors, and prototypes. They focused on "specifying the conditions" that make different kinds of boundary objects "more or less effective" in encouraging collaboration (Seidel & O'Mahony, 2014: 692). They advanced the research by suggesting that it is not just the features of boundary objects, but also actors' ability to use several supporting coordinating practices, including those aimed at scrutinizing, linking, and editing ideas, that determine their usefulness. While this research showed that not all prototypes are sufficient for encouraging integration, the literature has been silent on why and how the development and use of boundary objects can become a "center of intense conflict" that actively obstructs or subverts collaboration. Thus, I ask: Why and how might attempts to develop boundary objects manifest as conflicts that impede collaboration?

BOUNDARY OBJECTS AND COGNITIVE REPRESENTATIONS

To answer this question, I leverage the concept of cognitive representations: individual or group-level knowledge structures that provide simplified mental maps or images of the environment (Lakoff, 1987; Simon, 1991; Thagard, 1996). Actors form cognitive representations in environments characterized by high ambiguity—that is, a lack of clarity about the meanings of and connections between causes and outcomes (Weick, 1995). Cognitive representations reduce complex, ambiguous environments into their salient characteristics, making them tractable (Gavetti, 2012; Gavetti & Levinthal, 2000; Gavetti, Levinthal, & Rivkin, 2005; Gavetti & Menon, 2016; Menon, 2018). By imbuing ambiguous environments with "form and meaning," such representations "serve as a cognitive foundation for action" (Walsh, 1995: 291).

Cognitive representations are related to other knowledge structures that help boundedly rational individuals make sense of the environment (Simon, 1991; Walsh, 1995), including, for instance, cognitive frames. Actors see the world through cognitive frames—interpretive lenses that help them filter, order, and make sense of the past and the future (Goffman, 1974; Kaplan, 2008). Thus, while frames are like filters that color how individuals see and interpret the world, cognitive representations are like maps that reduce and represent reality, and thus provide a basis for action. In novel settings (for instance, in the nascent phases of industry development), unusual cognitive representations can serve as a foundation for innovation (Gavetti, 2012). For example, in the 1930s Charlie Merrill cognitively represented investment banking in terms of the supermarket business. This led him to pioneer Merrill Lynch's "financial supermarket" model that redefined the financial services industry (Gavetti & Menon, 2016).

Like other knowledge structures, individuals' cognitive representations are shaped by their histories, including their knowledge domains, professions, and industries (Gavetti, 2012; Gavetti & Levinthal, 2000). Charlie Merrill's cognitive representation, for example, was shaped by his deep experience in supermarket retail Thus, while frames are like filters that color how individuals see and interpret the world, cognitive representations are like maps that reduce and represent reality, and thus provide a basis for action. Individuals' histories determine what features of the environment they notice and include in their mental maps. Individuals from different domains or organizations can therefore form divergent representations of the same environment (Gavetti, 2012; Gavetti & Levinthal, 2000). For example, Gavetti and Rivkin (2007) showed how executives at Lycos and Yahoo! formed different representations during the nascent phases of the Internet portal industry; these were critical in shaping the firms' different strategies. However, whether and how divergent cognitive representations shape innovation or collaboration across boundaries in a single project has not been explored. In particular, the literatures on cognitive representations and boundary objects have remained largely separate: research has not explored how divergent cognitive representations may shape the creation of boundary objects, or vice versa.

METHOD

Research Context: The Smart City Industry

I studied the development of SmartBlock and SmartTown (both pseudonyms), two large-scale *smart city* projects. When I began the research, I hoped to explore how innovation can result from collaboration between actors from different knowledge domains. I chose to focus on smart city projects for two reasons. First, the projects had innovative aims, and sought to give rise to a nascent smart city industry, dubbed by observers as "the 21st century's first new industry" (Townsend, 2013: 30). This industry comprised new and existing ventures developing information technologies (IT) to make cities around the world more efficient, sustainable, and livable (Zuzul & Edmondson, 2017). The ventures focused on the development of new tools, such as residential solar panels and energy-efficient streetlights, connected by IT including sensors that could automate and control them based on data about occupancy rates and traffic flows (Alusi, Eccles, Edmondson, & Zuzul, 2012). These tools would be embedded into new and existing urban real-estate developments to make them technologically connected, responsive to occupants, and environmentally sustainable—that is, *smart*.

Second, smart city projects brought together groups of experts from diverse industries. The smart city industry emerged at the intersection of existing domains: technology and sustainable development (the smart component) and real estate (the city component). The technology domain comprised software and hardware engineers who developed smart city IT; the sustainable development domain comprised designers, architects, and urban engineers who thought about ways to implement the IT in urban settings. The real-estate domain comprised construction companies, real-estate developers, and real-estate managers that converted the projects onto pieces of land. A book on the industry noted that collaboration between actors from each domain was "integral to building, retrofitting, and managing the smart cities of the twenty-first century" (Edmondson & Reynolds, 2016: 29).

Research Setting

I tracked the development of two smart city projects, SmartTown and SmartBlock. Table 1 summarizes the projects and their timelines.

SmartTown. SmartTown was initiated in 2009 by TechCo[1], a startup founded by individuals with experience in the technology industry. TechCo's leaders aimed to develop a new smart city on a nearly 2,000-acre site located near a mid-sized city. They planned to develop the city in phases over 15–20 years, starting with a smaller residential community and technology cluster. SmartTown would be constructed sustainably, would rely on alternative energy sources, and would be embedded with sensors that would, among other functions, manage traffic flows and distribute energy use. The estimated cost of the project exceeded $5 billion (the residential community and technology cluster alone were estimated at $500 million), to be raised through a variety of sources including real-estate sales, technology sales, and private investment. To develop SmartTown, TechCo collaborated with a large number of firms, including Arch2, a small architecture firm, and ConsultCo and LandCo, well-known consulting and real-estate development firms. Figure 1 illustrates SmartTown's project structure.

I began research at SmartTown in late 2009 as part of an interdisciplinary team studying various aspects of smart city development. We were introduced to the project when a member of the team met TechCo's CEO at a smart city event. TechCo offered us extensive access to the project, allowing us to observe its development and operations in an unfettered way. When I began the field research, SmartTown was still in its earliest phase: actors were acquiring land, developing a master plan, and building technologies to embed in the city. I tracked the project until mid-2012. While this paper focuses on collaboration within SmartTown, the data collection also resulted in a paper focused on the dynamics within (Zuzul & Edmondson, 2017). That paper theorized that TechCo leaders' focus on building legitimacy blocked the firm's ability to learn, thus stalling its progress on important internal initiatives (Zuzul & Edmondson, 2017). In contrast, this paper considers the process that led TechCo's collaborators to withdraw from SmartTown and that fueled collaboration failure.

SmartBlock. SmartBlock was initiated in late 2009 by DesignCo, an organization focused on catalyzing innovation in its home country, and DevCo and EstateCo, real-estate development companies. The firms formed a cross-firm leadership team, and announced their $100 million investment into the project. They launched a competition to choose their designers, urban engineers, and architects, and, in late 2009, selected a winning team from almost 100 submissions. Over three years, the firms aimed to develop a smart, sustainable city block in a large city's formerly industrial area. The block, comprising several residential and office buildings, and a mixed-use public space, would be constructed using sustainable methods, would be connected with new technological solutions, and would emit almost no carbon. Figure 1 illustrates the project structure.

I was introduced to a SmartBlock leader by a colleague familiar with my research at SmartTown. Following a round of preliminary interviews in 2010, I began field research in early 2011. At this time, actors were finishing final designs and hoped to break ground within the year. I conducted the field research until mid-2012.

Leveraging comparative field data. I pooled data from the projects (e.g., Bechky & Okhuysen, 2011). This approach differs from that of planned multiple-case studies (Eisenhardt, 1989). My purpose was not to compare the outcomes of the two projects, but to examine the patterns that replicated across them (Bechky & O'Mahony, 2015). Pooling the data in this way allowed me to uncover surprisingly similar dynamics in two distinct settings. There were important differences between the two projects. The most obvious were size, timeframe, and cost: SmartTown was a larger, longer-term, and more expensive project by orders of magnitude. There were also differences in

[1] All company names in the paper are pseudonyms.

TABLE 1
Characteristics of SmartTown and SmartBlock

Aspect	SmartTown	SmartBlock
Project description	Smart, sustainable city	Smart, sustainable city block
Project scope	Entire city, starting with residential community and technology cluster	Residential buildings, office building, mixed-use public space
Project site	Greenfield area outside mid-sized city	Former industrial area in large city
Project size (acres)	2,000	5
Estimated cost ($)	>5 billion	<100 million
Project leadership	TechCo (technology)	Cross-firm consortium: DesignCo (design and innovation), DevCo (real-estate development), EstateCo (real-estate development)
Other actors involved	Real-estate development; architecture; consulting	Architecture; urban engineering; design
Launch date	Early 2009	Late 2009
Estimated completion date	2029	Late 2012
Period of data collection	Late 2009–mid-2012	Early 2011–mid-2012
Stage of development at beginning of research	Pre-Launch	Implementation

leadership: SmartTown was spearheaded by a single technology firm, while SmartBlock was led by three hierarchically equal partners. Finally, there were differences in the projects' state of completion at the time of the research: while I observed SmartTown unfolding in real time from the project's starting point, I tracked SmartBlock's earliest phases through archival sources triangulated with retrospective interviews. The differences amplify the generalizability of my findings, allow me to theorize boundary conditions, and strengthen confidence in the process I uncovered.

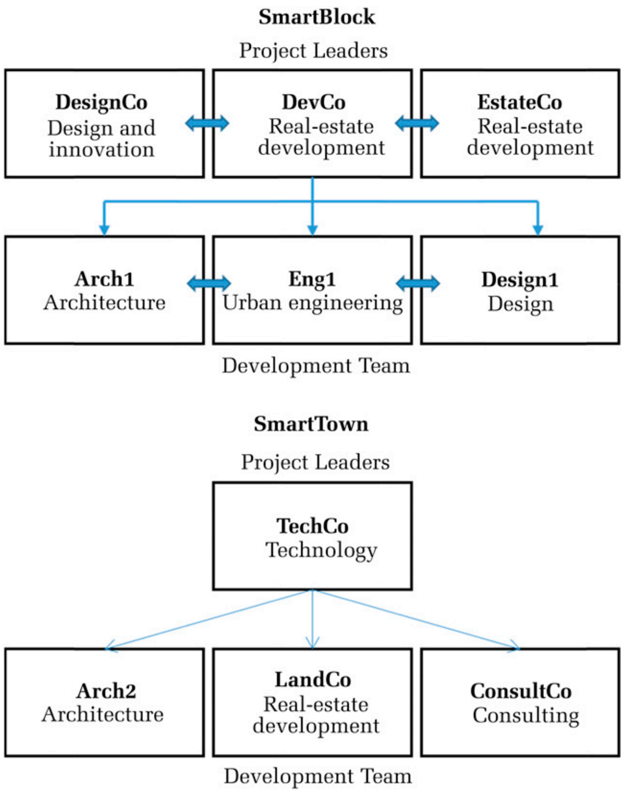
Data Collection

I gathered project-level data through interviews, observation, and document review, triangulating my emerging findings (Yin, 2015). I began data collection with the intention of tracking SmartTown and SmartBlock until their completion. However, both projects were placed on indefinite hold in mid-2012. At this point, I could no longer observe collaborative dynamics as they unfolded. At the same time, my interviews had reached a point of theoretical saturation, and were not yielding new insights. I therefore ended data collection.

Interviews. I conducted 104 in-depth interviews with 59 individuals across the projects, ranging from 60 minutes to three hours. All interviews were tape recorded and transcribed. Participants included actors from multiple firms, functions, and levels, including project leaders and employees responsible for day-to-day execution. The questions focused on understanding their experiences and perspectives on the projects. I questioned participants on what they thought about each project, their work, the challenges they faced, and how they resolved them. Whenever possible I interviewed the same individuals at different points in time, which allowed me to develop an integrated understanding of their evolving perspectives on each project.

Observation. I spent considerable time at each site, making six one-week to one-month visits to SmartTown, and three week-long visits to SmartBlock. When onsite at SmartTown, I spent the entire day in the field, shadowing employees, observing interactions, and attending all project meetings. At SmartBlock, I spent about five hours per day at the site, conducting interviews and (when possible) attending meetings. At both sites, I participated in casual gatherings (including lunches and dinners), and used these as opportunities to conduct informal interviews. I took extensive field notes during each visit, including detailed notes on what was said, descriptions of how individuals interacted, and ongoing personal reflections on unfolding events. When this seemed too invasive (for instance, during informal lunches), I typed my impressions as soon as possible. My presence in the field both generated data, and allowed me to build the trust and familiarity necessary to investigate sensitive phenomena, thus enriching my interviews.

FIGURE 1
SmartBlock and SmartTown Project Structure



Document review. I also collected archival documents from each site. At SmartTown, documents included successive business plans, presentations, and master plans for the city. I was copied on 105 emails exchanged between the leadership team of multiple firms. At SmartBlock, documents included project analyses, an internal blog written by DesignCo employees, and reports written by designers and urban engineers. Table 2 summarizes the data sources from the two projects.

Industry-Level data. Finally, I gathered primary and archival data to better understand the smart city industry. I conducted 14 interviews with industry stakeholders, including technologists, architects, urban engineers, and governmental officials working on smart city projects. I attended smart city conferences, and analyzed smart city articles as well as reports from various companies and think tanks.

Data Analysis

My analytical approach was inductive and open-ended (Strauss & Corbin, 1997). Like the data collection, the analysis unfolded over multiple years and considered many aspects of each project's progression. As noted, both projects were terminated before their completion. At SmartTown, both ConsultCo and LandCo left the project. At SmartBlock, all actors increasingly withdrew from the project: their focus shifted from innovating to simply completing the block. Actors across both projects described these outcomes as failures of collaboration. I thus focused my analysis on examining the process that led to these failures.

In the first stage of analysis, I constructed thick descriptions (Langley, 1999) of the projects. I wrote lengthy case studies that described each project's aims, history, and the backgrounds of the actors involved. I created chronological accounts of all major events, decisions, and changes. I engaged in narrative analysis (see Boje, 2001), constructing narratives that captured the stories told by the diverse actors involved.

In the second stage of analysis, I used QSR NVivo, the qualitative data analysis software, to engage in open coding of my interview transcripts, field notes, and archival data. I searched for themes that could capture similarities and differences across the projects, actors, and over time, generating nearly 100 emergent codes. I condensed this list to a smaller number of codes that seemed connected to project's failure of collaboration. These codes clustered into a set of 14 second-order categories. For example, one early category captured actors' *Cognitive Representations*. This category included all statements that reflected actors' mental maps of the projects or smart cities more generally. However, it was initially unclear what role cognitive representations played in the failure of collaboration. Similarly, the early category of *Emotions* (consisting of first-order codes including disappointment, frustration, contempt, and excitement) captured the starkly emotional ways actors often spoke about each project, as well as specific decisions and interactions. However, how emotions were connected to a failure of collaboration remained opaque.

In the third stage of analysis, I focused on bringing together my understanding of each project's path of development, and my emerging theoretical categories. I revisited the raw data, case studies, and NVivo codes to arrive at a set of "episodes of break-down," or conflicts in each project that actors described as critically connected to the eventual failure of collaboration. These conflicts were all identified by multiple actors as either

TABLE 2
SmartTown and SmartBlock Data Sources

Source	SmartTown	SmartBlock
Interviews		
Individuals (*n*)	41	18
Interviews (*n*)	70	34
Observations		
Field visits	6	3
Meetings	40	2
Presentations and press events	10	1
Approximate hours in field	800	100
Documents	Business plan, reports, emails	Reports, blog

leading to or having set the stage for project failure, and were described in highly emotional terms. I identified five conflicts (three at SmartBlock and two at SmartTown) and compiled the data on each. I had fully or partially observed three of these conflicts; two were described in interviews and archival documents.

In the fourth stage of analysis, I compared across the conflicts to uncover similarities and differences. Comparing the data with the literature on collaboration across boundaries, I recognized a connection to the theoretical concept of boundary objects. While the conflicts varied across a number of dimensions, each involved the creation or manipulation of an artifact that was meaningful to all actors. Intrigued by this discovery, I revised my research question and focused my analysis on understanding why and how the attempts to create boundary objects manifest as conflicts that blocked collaboration.

In the final stage of analysis, I continued working iteratively between the data and the literature on collaboration across boundaries. In so doing, I integrated a number of previously developed codes—including *Cognitive Representations* and *Emotions*—into a single process model that both authentically represented the data, and contributed to the literature. Although the model could not capture the exact experience of every individual involved in the project, its features and mechanisms appeared in multiple accounts. To validate the model, I reinterviewed and presented my results to two insiders: a designer at SmartBlock and a consultant at SmartTown. Their confirmations suggested that I had constructed a theoretical model that broadly captured the progression of both projects.

RESULTS

Understanding SmartBlock and SmartTown's devolution requires an appreciation of each project's starting point. The leaders and employees of the 10 firms I studied described each project as a strategic priority, and committed publicly to its successful completion. Both projects were launched with great enthusiasm in high-profile events. The press release announcing SmartBlock quoted a well-known government official who described the project as "an important step towards sustainable development." A real-estate developer described his early excitement about the project: "The goal is systemic change... We are a part of the change... We are turning everything around!" During SmartTown's announcement, a well-attended event that brought together the press, CEOs, and high-ranking government officials, a technologist described how the project represented nothing less than "the start of a new industry... [SmartTown will be] one of a handful of cities in the world that will serve as examples for cities in the future." An email from a LandCo developer to all TechCo employees announcing the collaboration described how: "We are fired up to work with you, and the whole company has been buzzing about the news... the interest is immense, almost unlike any other project!"

To make progress on the projects, SmartBlock and SmartTown actors structured collaboration around the development of objects that could integrate their expertise and work. SmartBlock actors sought to develop (1) in late 2009, a formal contract specifying each firm's responsibilities and deliverables; (2) in early 2011, a detailed project master plan, or a set of drawings representing what smart and sustainable solutions would be developed, how land would be used, where buildings would be located, and how they would be constructed; and (3) in mid-2011, a pro forma, or a document quantifying the development by projecting all revenues, costs, and financial returns.[2] SmartTown actors sought to prepare (4) in mid-2010, a financial deck (similar to a pro forma but consisting of a presentation rather than a document based on calculations), and (5) in mid-2011, a project master plan with similar goals to SmartBlock's.

[2] SmartBlock's pro forma development was not finished before the project disbanded in 2012; nonetheless, because early patterns were similar to those that characterized the development of other objects, I included it in my analysis.

In both projects, efforts to develop these objects manifest as heated conflicts that exacerbated differences between actors. For example, a SmartBlock architect described attempts to create a master plan as "a waste of time, energy, and work." He elaborated how the process of developing the plan "has led to very unsatisfying technical results, both on the performance and aesthetical side. You wonder how on Earth you got to that point!" Similarly, a SmartTown consultant described the attempt to create a financial deck as "really heated... It was amazing to be at the center of that, and to watch the arguments about it unfold... It was really, really painful." Next, I consider how and why actors' efforts to develop boundary objects manifest as divisive conflicts that set the stage for collaboration failure.

The Emergence of Two Forms of Ambiguity

SmartBlock and SmartTown were envisioned as pioneers of the nascent smart city industry. This extreme novelty gave rise to two early and simultaneous forms of ambiguity: *concept ambiguity* and *process ambiguity*.

"What is a smart city?": Concept ambiguity. SmartBlock and SmartTown's earliest phases were characterized by *concept ambiguity*: a lack of clarity about what smart cities are. SmartBlock and SmartTown were two of the world's first smart, sustainable, large-scale urban developments. Although a number of other smart city projects were announced around the same time, few had made significant progress. An industry observer described how, as a result: "There's no consensus about what... [smart cities] actually mean. When people talk about smart cities, they often cast a wide net that pulls in every new... [city] innovation" (Townsend, 2013: 15). In an interview, a SmartBlock architect explained: "There is no precedent for this kind of project." He elaborated: "We are building the first genuinely 21st century block." Similarly, a SmartTown actor reflected: "We're working on something that doesn't yet exist. We will be the first smart city."

"How do we build a smart city?": Process ambiguity. At the same time, SmartBlock and SmartTown's early phases were characterized by *process ambiguity:* a lack of clarity about how the process of smart city development should unfold. When the projects were launched, there were no established or accepted models indicating how smart cities should be designed and built. In 2010, an urban engineer familiar with smart city projects around the world explained this process ambiguity:

> The innovation ten years ago was around green buildings and things like dimmable lights. Now we have moved to talking about smart or zero-carbon cities. But nobody really knows what that means... The people who are leading these projects have never done anything like this before. And there is no real research on how smart cities should be developed.

Actors intended to develop each project in three broad phases:[3] the schematic design phase, when they would research, develop, and test potential ideas; the detailed planning phase, when they would commit to final development plans; and the construction phase, when they would build the urban spaces. However, they lacked shared ideas about what each phase would entail and how long it would take, and about who would lead development. As a SmartTown executive reflected during a planning meeting, "There is no template for building new cities." In particular, no single set of actors comprised a clearly dominant group with the accepted power to set the vision for the ideas and work of others. Would the technologists, designers, urban engineers, and architects guide the process of development, since they would build the technological and sustainable solutions that were necessary for a city to be "smart"? Or would the real-estate developers lead, since their efforts were critical in turning smart technology into a smart "city"? A SmartBlock architect elaborated: "This is a new way for us to collaborate. There is no model that exists for it." A SmartBlock urban engineer echoed this idea: "It's unfamiliar who should be leading whom. Are we leading? Are they? Sometimes we have misunderstandings."

Ambiguity Gave Rise to Divergent Smart City Representations

In response to both kinds of ambiguity, as they began their initial work, groups of actors formed divergent cognitive representations about the projects. Two representations were prevalent in each project: the *smart* representation, and the *city* representation. Next, I describe these representations, which are summarized along with illustrative quotes in Table 3.

[3] Although the phases were not explicitly termed this way in each project, plans for both adhered to the same general pattern captured by the titles.

The "smart" representation. SmartBlock and SmartTown technologists, designers, urban engineers, and architects formed what I term the *smart* representation. In the earliest phases of project development, these actors were tasked with putting together conceptual plans for cutting-edge technologies and solutions that would make the projects smart and sustainable. At SmartBlock, DesignCo designers conducted ethnographic studies and prepared reports evaluating the current state of worldwide sustainable development, and considered how the project could impact this trajectory. They evaluated whether and how the process of developing the project could result in "changed building permits," "codes," and "legal frameworks" that could "have a systemic impact" (SmartBlock designer). The urban engineers developed and tested plans for new technologies that could decrease the project's carbon footprint, including "building-integrated photovoltaics that are at the brink of being commercially viable" (SmartBlock urban engineer). At SmartTown, the technologists focused on coding an "urban operating system" consisting of "networks that can connect the whole city" in order to make it smart and sustainable (SmartTown technologist). Architects across both projects developed "concept designs" (SmartTown architect) consisting of drawings, plans, and 3D models that captured the overall form and aesthetics of each project, including how technology would be used, while leaving the real-estate development details unspecified.

Because their tasks and expertise revolved around the conceptual planning of smart and sustainable solutions, the technologists, designers, urban engineers, and architects began to represent smart cities as "living laboratories," "reference projects," or "sandboxes" for the development and demonstration of sustainable technologies and processes. A designer described SmartBlock's purpose as providing an "alibi to address a broad set of issues around sustainable development." Similarly, "SmartTown is a means to an end," TechCo's CEO explained, "and that end is the demonstration and distribution of technology." Another TechCo executive reflected: "The genius of the idea behind SmartTown is that it is much more than just a real estate play; in fact, real estate is just a minor part of it."

Actors with the smart representation defined innovation in each project as the development of cutting-edge technologies and processes that would be applied to other smart cities worldwide. A SmartBlock urban engineer described how, "We are not interested in a one-off... In 20 years, our success will be measured by whether the insights from this project have spread." Similarly, during a firm-wide operations meeting, TechCo's CEO described how SmartTown's success would be defined by the project's ability "to replicate and spread technology elsewhere."

Because the smart representation privileged the development of replicable technological and sustainable solutions, these actors believed that technologists and sustainable development experts should lead the process of smart city development. A SmartBlock designer explained "Setting the broader objectives—that is our role." They saw the development of real estate as secondary; as a member of TechCo's board stated in a planning meeting, "Ultimately, we won't have to stick with traditional...construction because of our new technologies and methods."

The city representation. At the same time, actors with backgrounds in real-estate development, including the developers and consultants, formed what I term the *city* representation. In each project's earliest phases, these actors were tasked with working on development plans for urban spaces. At SmartBlock, the real-estate developers produced building targets based on the number of residents and apartments the site could support. They generated estimates for the apartments' sale and rental prices, and met with, evaluated, and engaged subcontractors that would construct the project. At SmartTown, the real-estate developers and consultants analyzed the project site's potential and physical limitations, prepared plans for purchasing the land, and developed targets for revenue streams. "Our role has been to realize what the realistic ideas are, and how we can make them happen," a SmartBlock developer explained. Similarly, a SmartTown real-estate developer described his task as "the conversion of this fantastic set of ideas into reality on a piece of land."

Because their tasks and expertise revolved around the planning of how SmartBlock and SmartTown would be developed, constructed, and leased or sold, the real-estate developers and consultants formed the city representation. They represented smart cities as real spaces where people would want to "live, work, and play" (a common SmartTown refrain). They saw each project as an attempt to build an attractive, livable, and hence sellable urban development; as a SmartTown real-estate developer described, a "real city rather than a few buildings."

The real-estate developers' and consultants' definitions of innovation centered around the development of high-quality urban spaces that satisfied potential buyers, and that could be sold easily at high prices. For instance, a real-estate developer described

TABLE 3
Ambiguity and Divergent Cognitive Representations: Illustrative Quotes

	Kind of Ambiguity	"Smart" Representation	"City" Representation
Definition	*Concept ambiguity:* Lack of clarity about what smart cities are, and how their success should be measured.	Smart cities are reference projects aimed at testing and demonstrating smart, sustainable technologies.	Smart cities are developments embedded with solutions that make them liveable and sellable.
Illustrative Quotes	"We are so different that you can't put us into any category... You can't really map us onto anything."—Technologist, SmartTown	"We are using the city block...to come up with a low-carbon solution."—Designer, SmartBlock	"This project is about putting together research and real buildings."—Real-estate developer, SmartBlock
		"We are not a real-estate project, we are a technology project with real-estate."—Technologist, SmartTown	"[We want] to create an environment in which people want to work, live, and play."—Real-estate developer, SmartTown
Definition	Process ambiguity: Lack of clarity about how the process of smart city development should unfold.	Technologists, designers, urban engineers, and architects should guide development; technological and sustainable solutions should be prioritized.	Real-estate developers and consultants should guide development; real-estate functionality and saleability should be prioritized.
Illustrative Quotes	"There is no precedent for this kind of project. Everyone is working together, but this is a new way for us to collaborate. There is no model that exists for it."—Architect, SmartBlock	"We have a vision of networking and applying technology to the city from the planning stages."—Technologist, SmartTown	"We should start by setting targets [for performance and cost]...and then think about what should be done with solar panels, smart things, this and that."—Real-estate developer, SmartBlock

how the most "innovative part" of SmartBlock was that it represented "a mixed-use project... That's something new, and something better for residents." They believed the success of the projects depended on their ability to "at the end of the day...build some buildings" (SmartTown real-estate developer). For instance, a SmartBlock developer described success as the project's ability to "differentiate itself in the marketplace." He elaborated: "The most important thing is... how well the project is performing in the market."

Because the city representation privileged the development of real urban spaces, these actors believed the requirements of the land and buildings should determine what technological solutions would be developed, and not vice versa. A SmartTown real-estate developer explained how he believed the process of smart city development should unfold. He emphasized how the developers should guide the process by thinking through realistic, sellable ideas—and only then should technologists "add a lot more technology" to the plan and "into the fabric of the buildings." These actors believed that getting to a real set of buildings quickly would be critical. As one actor dramatically exclaimed during an early meeting at SmartTown: "We've got to f***ing start building!"

Thus, SmartBlock and SmartTown actors formed distinct cognitive representations about smart cities. To be clear, these differences did not reflect conflicting subgoals or incompatible incentives: all the actors had a vested interest in completing an innovative, timely, sellable project. For instance, TechCo technologists (who held the smart representation) and DevCo and EstateCo real-estate developers (who held the city representation) could only begin to generate profits if and when parts of SmartTown and SmartBlock were sold. While some of the other actors (including SmartBlock architects and SmartTown consultants) were paid for their work on an ongoing basis, all expressed an interest in developing a project on time, within an agreed-on budget, and that would solidify their firms' reputations as leaders in the smart city space.

The Development of Boundary Objects Manifest as Matter Battles

Next, I describe how divergent cognitive representations shaped *matter battles* that fueled collaboration failure (summarized in Table 4). I illustrate my findings by describing the development of a master plan at SmartBlock (2) and a financial deck at SmartTown (4).

Cognitive representations shaped incompatible ideas about important choices. As their work unfolded, SmartBlock and SmartTown actors shifted from working on separate tasks to working together to develop boundary objects that could combine their knowledge and ideas. For example, after completing their formal contract, SmartBlock actors structured collaboration around the development of a detailed master plan—that is, a two-dimensional plan for the block—that would combine the design team's conceptual plans with the real-estate developers' ideas about urban development. During the schematic design phase, SmartTown actors worked to develop a financial deck estimating the project's future revenues, costs, and financial returns. The deck would integrate the work of the TechCo technologists, who had been planning and thinking through technological solutions (including costs and potential for monetization), and ConsultCo consultants, who were well versed in developing similar documents for other complex projects (including real-estate developments).

Both objects were critical for moving forward, since they would guide how the cities would be built and financed. To develop these objects, actors had to make a number of interconnected, strategic decisions about each project. Because SmartBlock's master plan would provide a model for the block's development, it had to represent the smart and sustainable solutions, construction materials, and energy sources that would be deployed. It also had to detail building size and orientation, and the uses for public spaces. Similarly, to develop the financial deck, SmartTown actors had to choose realistic modeling assumptions, including how much both real-estate and technological development would cost, how many customers they would attract, and how much revenue the city would generate from leases to technology partners and sales of real estate.

Across both projects, actors made decisions and worked on and with the objects in intense face-to-face meetings. At SmartBlock, actors began developing the master plan remotely, discussing and deciding on different options over email and biweekly videoconferences. About a month into detailed master plan development, they switched to a colocation scheme. On Mondays and Tuesdays, all actors met physically in day-long planning sessions where they listened to each other's proposals and ideas about how the master plan should look and function, made decisions, and set the agenda for the following week. On Wednesday through Friday, the architects worked on implementing the agreed-on decisions into the master plan, while other actors worked on preparing proposals for the following week. At SmartTown, ConsultCo consultants spent three days per week sharing TechCo's working space. The development of the financial document was led by a senior ConsultCo consultant. For a period of several weeks, the consultant spent most of his time building the document. The technologists reviewed his work, gathering frequently around his computer to comment on the assumptions, model, and emergent object.

However, by the time they began working together in this way, actors had developed divergent cognitive representations that shaped different—and often incompatible—preferences about important choices. For example, to develop the master plan, SmartBlock actors had to decide on the construction materials that would be used for the buildings in the block.[4] In one of the early planning meetings, the lead urban engineer suggested the use of timber. This option resonated with actors with the smart representation, who saw an opportunity to demonstrate and catalyze the potential of this sustainable material "throughout the construction industry" (SmartBlock urban engineer). The use of timber aligned with their representation of the project as testing and promoting smart and sustainable solutions to drive broad change. An urban engineer explained how, "Building with timber really isn't done [in SmartBlock's region]. It will be pretty transformational if we can work out [how to]. . . implement it at scale."

In contrast, actors with the city representation expressed skepticism about timber, explaining that the material's performance had not been proven in the region's specific conditions. It was not clear, for instance, whether timber construction would meet fire codes, or appeal to local buyers. Building with a more conventional material aligned with their representation of the project as developing a context-appropriate and sellable urban space. To determine whether timber would be an effective material, a real-estate developer explained, "You just have to know the local conditions. 'Oh, it's possible in other places'—that that just doesn't work here!"

[4] Although I focus on the decision about construction materials, master plan development involved similar disagreements on other choices, including on the use of photovoltaic (solar) technologies, indoor air quality standards, and building massing.

TABLE 4
Summary of Boundary Objects and Conflicts

	Boundary Object	Summary of Conflict	Implemented Choice	Emotional and Cognitive Reaction	Illustrative Quotes
(1) SmartBlock contract(2009)	DesignCo designers, and DevCo and EstateCo real-estate developers, have to develop a formal contract specifying responsibilities and fees of design team (architects, urban engineers, other designers).	Actors engage in disagreements about the formal targets that should be written into the contract. Designers argue for specifications typical of large-scale innovation projects; real-estate developers argue for targets typical of real-estate projects.	Real-estate developers concede. Contract is embedded with few formal real-estate targets .	Real-estate developers respond with blame and anxiety; believe that designers do not understand requirements of building projects.	*Conflict:* "The process of contract negotiation was a challenge. . . We had to get into these huge discussions."—Designer *Emotional and cognitive reaction*: "There were all these workshops [about contract negotiation]. . . But DesignCo was just having their own ideas, and not really interested in ours. . . Their expectations and our real life never really met."—Real-estate developer
(2) SmartBlock master plan (2011)	All actors have to create a master plan representing how land will be used, what infrastructure will be developed, what technology will be embedded, where buildings will be located, and how they will be constructed.	Actors engage in disagreements about multiple features, including building material (actors with smart frame argue for timber; actors with city frame for concrete); use of photovoltaic (solar) technologies; indoor air quality standards; building massing; development of individual balconies vs. shared garden; etc.	Actors on both sides acquiesce on certain points. For example, they decide to construct one building in timber, and others in concrete. Once choices are made, they are drawn into a physical plan that acts as template for construction.	All actors respond with disappointment and frustration. Actors with smart frame believe real-estate developers do not care about sustainability; real-estate developers believe that actors with smart frame lack realism in their ideas.	Conflict: "[The timber decision] was an enormous missed opportunity. . . The engineers did good enough work to get it through, and with a bit of willingness, we should have been able to do so. But the real-estate developers were against it. . . In the end, they said, 'We're going to do concrete, even though it has worse [sustainability] performance.'"—Architect

TABLE 4
(Continued)

	Boundary Object	Summary of Conflict	Implemented Choice	Emotional and Cognitive Reaction	Illustrative Quotes
					Emotional and cognitive reaction: "We will have solar. It seems that it's really important for [DesignCo]. For us. . . putting these outrageously expensive things just for the show of it is a little bit. . . [*sarcastically*] yeah. . . DesignCo wants to have a show, but we're realistic."—Real-estate developer
(3) SmartBlock pro forma (2011)	DesignCo designers and DevCo and EstateCo real-estate developers have to develop a document quantifying projected revenues, costs, and other financial returns.	Actors engage in disagreements about how to quantify smart and sustainable technologies. Actors with smart frame argue for quantifying them as investments; actors with city frame for quantifying them as costs.	Because of failure to agree, pro forma is not developed before project is rejected by board.	All actors respond with frustration, disappointment, worry. Designers believe real-estate developers do not understand innovation; real-estate developers believe that designers do not understand construction.	Conflict: "It's only when you have the spreadsheet with numbers that you realize—oh [s**t]—we're talking about different things."—Designer Emotional and cognitive reaction: [During the pro forma discussion] "We realized [the real-estate developers] wanted to. . . do something that was very close to what they do normally. They weren't pushing themselves. That's not innovation."—Designer
(4) SmartTown financial deck (2010)	TechCo technologists and ConsultCo consultants have to develop a financial deck quantifying the project's projected revenues, costs, and other financial returns.	Actors engage in disagreements about financial assumptions. Technologists argue for modeling figures typical of technology projects; consultants for modeling figures typical of real-estate developments.	Consultants agree to benchmark on typical technology projects.	Consultants respond with anger and exasperation; believe that technologists are delusional about project.	Conflict: "It was really heated. . . It was amazing to be at the center of that, and to watch the arguments about it unfold."—Consultant Emotional and cognitive reaction: "The assumptions [the technologists] wanted to make were crazy!"—Consultant

TABLE 4
(Continued)

	Boundary Object	Summary of Conflict	Implemented Choice	Emotional and Cognitive Reaction	Illustrative Quotes
(5) SmartTown master plan (2011)	TechCo technologists, Arch1 architects, and LandCo real-estate developers have to agree on a master plan representing how land will be used, what buildings will be developed, and what technology will be embedded.	Actors engage in disagreements about how detailed the ideas in the master plan should be. Technologists and architects argue that the technological and sustainability solutions should be specific, and the real-estate less precise. Real-estate developers argue that the real-estate targets, including land use and occupancy rates, should be developed in detail.	Technologists decide not to develop real-estate targets and requirements in detail.	Real-estate developers respond with frustration; believe that technologists do not understand requirements of building a city block.	Conflict: "Thinking about the project in early brainstorming sessions was really fun. . . Now, it's gotten very difficult. We've been fighting a lot about the master plan."—Architect Emotional and cognitive reaction: "This is going to sound really demeaning to TechCo, but we know this, because the property development industry is highly developed. . . We're dealing with IT-based people, which is a very different world. At the end of the day, in the IT world, all they have to do to make their good idea marketable, normally, is rent some service space, and that's pretty cheap. What these guys would like to do is go and build some buildings, and that's not cheap."—Real-estate developer

At SmartTown, divergent cognitive representations shaped incompatible preferences about the assumptions that would be embedded into the financial deck. Because actors with the smart representation saw SmartTown as a technological sandbox, they believed the project's profits would be driven by technology sales. They hoped to stimulate sales by leasing much of the space in the city to partners that would work to develop the technologies. They also believed their financial assumptions should be typical of those common in technology projects; as SmartTown's CEO explained, "Our numbers are pretty standard in the technology industry." In contrast, because actors with the city representation saw SmartTown as an attempt to deliver a real city, they believed its profits would be driven by real-estate sales. They thus believed its financial trajectory would be similar to that of more traditional real-estate developments. This difference was visible in an exchange that occurred one morning as technologists and consultants gathered around a laptop to comment on the financial document:

> Consultant: "Does this revenue model exist in any other industry?"
>
> Technologist: "That's the basis of the tech industry... Other cities' models are all about real estate."
>
> Consultant: "But why doesn't our model focus on the real estate, and just have the tech piece on the side?"
>
> Technologist: "Because the technology has to be central."

This exchange illustrates that, even sitting side by side, the technologist and consultant represented SmartTown in different ways that shaped their ideas about the object.

Incompatible ideas drove heated discussions about choices. Because of these differences, actors in both projects engaged in lengthy discussions about the best ways forward. At SmartBlock, the design team compiled and presented research on the use of timber, including its sustainability implications, and how it would affect public perceptions of the project. Following the presentations, actors debated the use of timber in heated discussions. A designer described their divided opinions: "[The real-estate developers] were concerned about the management aspects of a timber building... And DesignCo was very open to it, and pushed for it. Those were the battle lines in the end." An architect described these battle lines as "quite a fight" that unfolded over several weeks. An urban engineer described this prolonged "controversial decision:"

> [The developers] said, "We don't do timber construction"... They thought we were nuts... They were almost dismissive of the analysis... We had to say, "Let's talk through this. What is your reaction to timber due to?"... We had to just keep coming back to it and keep coming back to it—and just be complete pains in the [a**] about it.

At SmartTown, actors' differences collided in a heated argument that occurred several weeks into the financial deck's development, when the technologists and consultants had to decide on a final customer growth trajectory to include in the model. Early one afternoon, while other SmartTown actors worked independently on their computers, three technologists asked the lead consultant to show them the financial model. As a technologist reviewed the document, he became visibly upset. He loudly exclaimed, drawing the attention of everyone in the room: "This model is a joke!" The following excerpt from the disagreement, which unfolded loudly over nearly an hour, illustrates how the consultants and technologists' divergent cognitive representations shaped incompatible ideas about the model:

> [The consultant begins to explain the model, and a technologist cuts him off].
>
> Technologist 1: "How did you get to numbers like that? The model is right, but the assumptions in it are all f-ing crazy!.... This is the technology industry—this is not a consulting business!"
>
> Consultant: "I don't think the real-estate assumptions are incorrect here."
>
> Technologist 1: "... But you're comparing us to typical real-estate buildings, not smart buildings. The sophistication of the model is OK, but the assumptions are just wrong."
>
> [After additional back and forth]:
>
> Technologist 1: "You guys don't understand the numbers of tech *at all*... I'm not being disrespectful, but this is a property development plan."
>
> Technologist 2: "It's a tech plan with a bit of a shift—not a paradigm shifter."
>
> Technologist 1 [with disgust]: "That's *not* a tech plan."

Facing pressure, actors resolved discussions by making divisive decisions. At both SmartBlock and SmartTown, actors could not move on with planning before completing each object. A DesignCo designer described the shared pressure to complete the SmartBlock master plan on time: "[The urban engineers] have 15 people on the production of this thing, and they need to just crank stuff out." A real-estate developer agreed: "We should not discuss things for two, three, four, weeks.... We should just make choices. And when we have made the decisions, we should be backing them up [with action]."

Temporal pressure can leave actors with little time or interest in exploring multiple meanings and interpretations (Kellogg et al., 2006). Thus, across both projects, rather than building common ideas, the actors agreed to decisions that would allow them to move on from their prolonged discussions about each object. For example, SmartBlock actors decided that DesignCo's new office building, part of the block, would be constructed with timber, and all other buildings would be constructed with concrete. At SmartTown, the consultants agreed to change the assumptions in the financial deck to those proposed by the technologists.

But at both projects, actors interpreted these decisions as privileging others' cognitive representations while violating their own. At SmartBlock, actors with the smart representation interpreted the decision to relinquish plans for an all-timber block as nothing less than "an erosion of ambition" (DesignCo designer). They saw the decision as prioritizing the real-estate developers' view of the project as an urban development rather than a smart project, while also marginalizing their own contributions. An architect, for instance, explained how this outcome meant, "The project doesn't achieve at the level we were all aiming at... There are technical aspects that are not as innovative as they could have been. That's the pity."

In contrast, for actors with the city representation, agreeing to a single timber structure meant acquiescing to "solutions brought up... by people who don't know our situation here" (EstateCo developer). A real-estate developer elaborated how the decisions made in the master plan prioritized the work and perspectives of actors with the smart representation:

> The engineers and architects didn't like to listen to us. They wanted to work on their own: "Don't come here, don't tell us, we know how to do it." They should have been more open to collaborating. [Architects and engineers normally know] what is the local situation, and what are the real-estate constraints... But they weren't open to that... We have gotten the message quite strongly from their side that this wasn't a real collaboration.

At SmartTown, actors with the city representation believed the assumptions embedded into the financial deck prioritized the technologists' view of SmartTown as a technology project, rather than a viable real-estate development. Reflecting on the decisions that had been made, a consultant exclaimed: "There is no real-estate project that can grow that quickly!" At the same time, they believed the decision invalidated their prior work, and went against their ideas about how SmartTown's process of development should unfold. One consultant reflected in an interview: "Our professionalism was being tested. But what were we supposed to do?" He elaborated that the lead "had been pushing back," but that, because of the need to move on with planning, "He really had no choice."

Decisions reified cognitive representations into material outcomes. Disagreements do not always have perilous consequences for innovation projects (e.g., Jehn, 1995). However, the materiality of SmartBlock and SmartTown's intended outcome—the fact that both represented attempts to create a lasting, difficult-to-change city that would serve as a reference for future developments—imbued the disagreements around boundary object choices with deeper significance. The actors understood that the decisions they made would have permanent, irreversible consequences for each city. A SmartBlock designer elaborated on this idea:

> When you're translating ideas into something physical, decisions have material implications. You can't agree to disagree, or try multiple options. You can only put a building in one place. You can't please multiple points of view. You have to make one decision.

Thus, actors interpreted decisions that violated their cognitive representations with heightened emotion: they saw them as objective indications that the city they would build would not be the city they had imagined. An architect explained, with audible disappointment: "In the drawings, the project is still pretty good... It's just *[pauses]*: I'm always seeing that gap between the promise and the reality." A real-estate developer echoed this idea: "In the houses... We really were expecting something else. We wanted to have something else. But they are really expensive and nothing special." Another architect explained his perspective on the master plan decisions. His comment reflected the idea that the permanence and irreversibility of a material city—one that would serve as a reference point for future smart city development—lent great weight to all perceived missteps:

> The project... will become iconic in the city. And there's the rub: because it will have an iconic significance, many people will focus on it... The end result is what we will be judged for—and nobody will care about the rest. And there will be a danger of [people] looking at it... and they will find some aspects that are not as innovative as they could have been. That's the pity. It would not have been too difficult to go the extra mile [in master planning] to get there. But it has been quite a fight.

The reification of cognitive representations evoked negative emotions and simplifying stereotypes. Actors thus responded to the disagreements with strong frustration, irritation, disappointment, anger, and even contempt and hostility. Following the disagreements, they began describing each other through simplifying stereotypes, emphasizing the differences between "us" and "them," and blaming each other for the suboptimal outcomes. At SmartBlock, actors with the smart representation increasingly described their collaborators as, in the words of a SmartBlock architect, "Stuck in traditional ways of thinking and working." They described the timber decision by emphasizing the real-estate developers' inability to recognize innovative solutions and think about the project in the long-term. An architect elaborated on this idea, even suggesting that the real-estate developers misrepresented their ideas to hide their ignorance and fear of innovation:

> The [real-estate] developers presented their fears with regards to timber... But I think their excuse was just camouflage for the real reason, which is skepticism and ignorance of the medium. They claim the timber construction would not have been taken well by their market, and that people are used to different structures and so on... I think it's just camouflage for the fear of getting involved in technical construction that is unknown to them, with a certain amount of risk.

Actors with the city representation, in contrast, reflected on the disagreement by blaming their collaborators for their lack of understanding of real-estate development or construction. For instance, a SmartBlock real-estate developer explained the project's problems by drawing a clear distinction between "us" and "them": "Of course, DesignCo is not a professional developer. We are professional developers. So in DesignCo, they were expecting it would be so easy. Well, it's not." She blamed her collaborators for the battles about the master plan development:

> It was really hard to imagine what they [the designers, architects, and urban engineers] understood and what they didn't. There were many things we took for granted—that these are things we don't have to explain. Basic, basic, *basic*! Then it turned out they had very different expectations and thoughts about them.

At SmartTown, the consultants complained that the financial deck revealed the technologists' ignorance about real-estate development. For example, over dinner two days after the deck's completion, a SmartTown consultant explained that the technologists were just "groping at" technological ideas "without understanding the potential to execute them" on a real-estate development. SmartTown technologists complained how the deck revealed that the consultants did not understand the project, yet felt they could assert their views and ideas. For instance, a technologist reflected on the development of the deck in an interview:

> [The consultants] struggle a bit. They'll sometimes come at a problem with either no context or they'll make independent decisions on certain things that are strategically poor. That drives me crazy. And then we'll assert ourselves. Sometimes we don't want their opinion, and I don't have the time to educate them... I'm not there for their personal development... That caused the conflict last week. They presented content that was just so off in so many different areas.

He elaborated on his view that the development of the deck revealed that the consultants were incapable of understanding innovative models:

> If the model that we had was more generally shared in the industry—if it was something that was more common—they would have it down like they do other models... It's new, it's got lots of moving parts to it... It's a fast-moving project with fast-moving situations so it's tough for them [to understand].

Thus, for all actors, the decisions made about the master plan and financial document took on a deeper significance, and became a catalyst for negative emotional and cognitive dynamics, including blame, resentment, and stereotyping.

Repeated Conflicts Led to a Failure of Collaboration

Because they were so frustrated by the repeated conflicts, and because they increasingly viewed their collaborators as incapable of delivering innovative or realistic projects, actors began to question the viability of the collaborations and even the projects themselves. There were instances of integration, synthesis, and intermediate success within each project: for example, SmartBlock actors convinced their country's major energy provider to create a clean energy mix specifically for the block; SmartTown actors won a number of awards for their innovative ideas about smart cities. However, the benefits of these positive moments did not counterbalance the negative effects of the repeated conflicts. As a SmartBlock designer described, frequent conflicts ensured that "collaboration sure makes for painful day-to-day operations." He elaborated:

> When we got into the actual development of the project, it stopped being fun. That elation that came from the quick and easy successes [in the early phases] just doesn't happen very often. Now, everything is hard. That's because we're trying to figure out how to make this thing real in the world.

A SmartBlock architect succinctly summarized the dark tone that came to characterize both projects: "It has been a nightmare."

At SmartBlock, hoping to avoid further protracted disagreements between individuals they viewed as fundamentally different, actors limited their work to achieve the minimum requirements set out by the contracts. Their aims shifted from innovating to simply finishing. A real-estate developer explained the progression of her thinking on SmartBlock:

> Developer: Initially, the scope was. . .phew. . .we want it all. . . We basically wanted to change the world.
>
> Researcher: And what's your goal now?
>
> Developer: [*Laughs*] Just get it done.

Unsatisfied by the low level of innovation, in mid-2012 DesignCo's board rejected the final project proposal—including the master plan—the collaborators had developed, and SmartBlock was called off.

At SmartTown, both the consultants and the real-estate developers stopped working on the project entirely. In a firmwide meeting in 2012, TechCo's CEO categorized the relationships with the real-estate developers as well as the consultants as two of the "lowlights" of the project. He described the engagement of the real-estate developers as: "At best, humorous. . . It hasn't been a positive relationship. In fact, quite the opposite." As for the consultants, he explained: "I don't trust them as far as I can throw them."

Thus, across both projects, conflicts led critical groups of experts to withdraw from the projects; the collaborations were abandoned. The DesignCo project leader reflected on the failure of collaboration, highlighting the importance of the creation of objects that both revealed and reified divergent cognitive representations:

> The fundamental challenge that we had was. . . our disposition, our mental references. When we'd say, what do we mean by innovation—we realized quite late with our partners we were saying the same words but meaning different things. It's only when we'd get to the hard bits—for example, when we had the discussion about return on investment [in the pro forma battle]—that we began to realize. . . we were talking about different things. It's only when you have the spreadsheet with numbers that you realize, "Oh [s**t], we're talking about different things."

He went on: "This hasn't been a happy ending. . . We were thinking about systemic change. . .. The apt title for what we just went through is systemic failure."

DISCUSSION

Despite differences in SmartBlock and SmartTown, analysis of their devolution revealed a strikingly robust pattern. In this section, I combine the above findings with the literature on cross-boundary collaboration to propose a process model, illustrated in Figure 2, that explains why and how attempts to develop boundary objects can manifest as divisive conflicts that derail collaboration.

Many innovation projects are characterized by extreme novelty. For some, novelty is an environmental feature; for instance, surgeons, anesthesiologists, and nurses in hospital trauma centers confront new and unpredictable patient complications that require rapid and error-free collaboration (Faraj & Xiao, 2006). For others, novelty is a project-level feature. Projects that bring together individuals who are working together for the first time, without industrywide norms governing how they should interact (e.g., Battilana & Dorado, 2010; Levina & Orlikowski, 2009), or who are leading the emergence of new or nascent industries (e.g., Zuzul & Edmondson, 2017), lack established precedents that can provide a template for effective collaboration. This novelty generates ambiguity—that is, a lack of clarity about the meanings of and connections between causes and outcomes (Weick, 1995). At SmartTown and SmartBlock, extreme novelty gave rise to two simultaneous kinds of ambiguity.

Actors lacked clear guidelines and shared ideas about what each project was (concept ambiguity), and how it should be developed, including who should lead its creation (process ambiguity).

Individuals make sense of ambiguous situations by forming cognitive representations (Lakoff, 1987; Simon, 1991; Thagard, 1996). At SmartTown and SmartBlock, ambiguity created space for multiple—and incompatible—cognitive representations. As they began their work, groups of actors from diverse knowledge domains formed divergent representations about the smart city concept (including the definition of innovation and relevant measures of success) and process of development (including who should lead creation).

Because cognitive differences are usually not verbalized (Cronin & Weingart, 2007; Kaplan, 2008; Leonardi, 2011), early in each project, actors' divergent representations were undetected and uncorrected. However, as is often the case in novel projects (Carlile & Rebentisch, 2003), actors soon moved from working independently to structuring their interactions around the creation of objects that could integrate their expertise, including contracts, project master plans, and financial documents and presentations. The development of these objects was necessary to make progress, and occasioned the selection of important project choices; for example, how each city would look (including the choice of building materials), and how its development would be financed (including the choice of financial assumptions).

The literature has described similar artifacts as boundary objects (Bechky, 2003a, 2003b; Carlile, 2002, 2004). At SmartBlock and SmartTown, however, artefact development development proved problematic. Actors' divergent cognitive representations led to incompatible ideas, and triggered heated disagreements and debates about each object. And because the projects could move on until the objects were developed, rather than prolong their contentious debates, actors made decisions that were aligned with some representations while violating others.

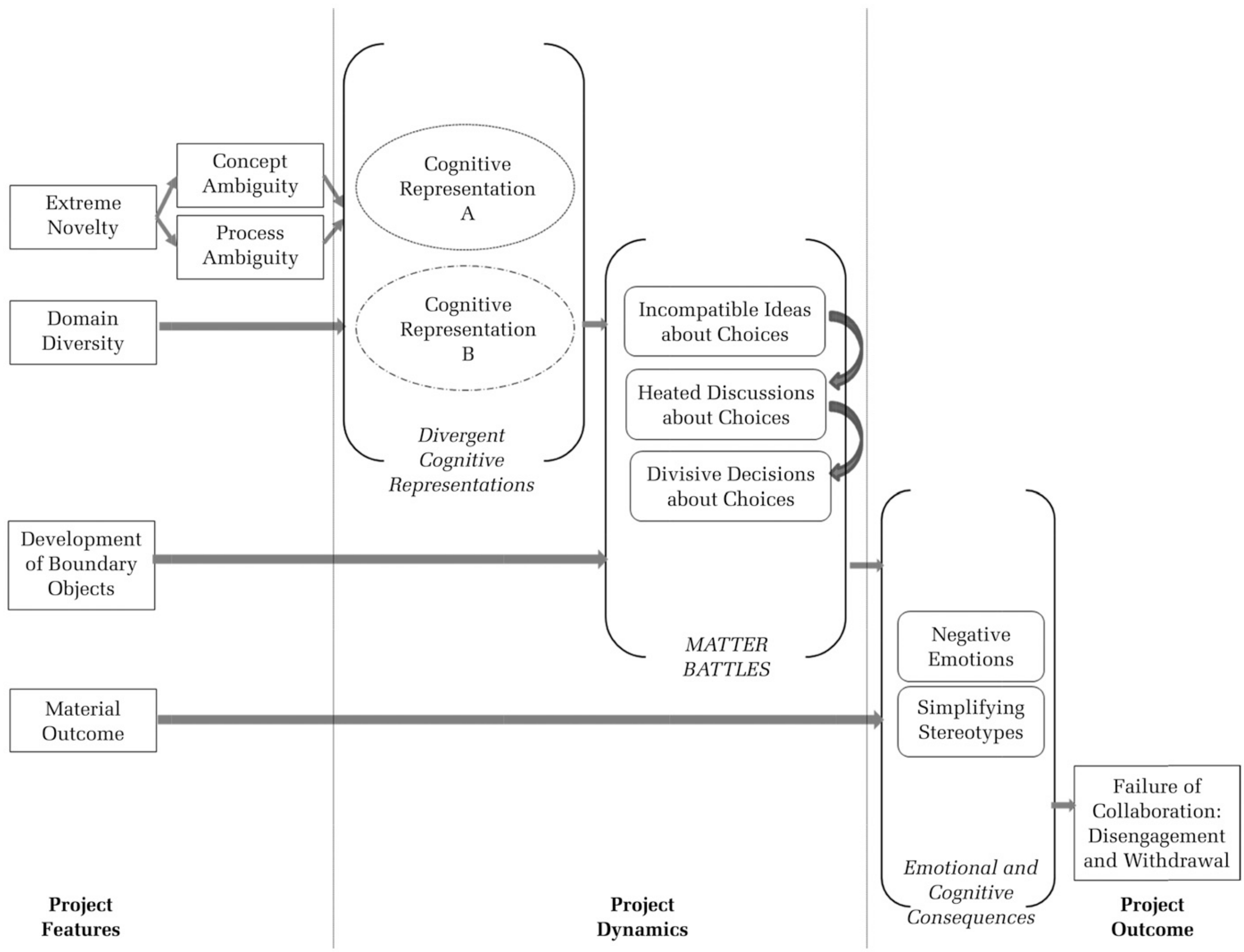
Critically, actors across both projects understood that, once implemented, their decisions—including those that violated some cognitive representations—would become enmeshed into a permanent, irreversible material outcome. The projects, after all, were oriented toward the creation of material cities that would occupy physical space, and that (once built) would be difficult to change or reverse. For instance, at SmartBlock the decision to construct a timber building affected all other elements of the city; once the building was completed, it would be both expensive and difficult to reverse. At SmartTown, the decision about financial assumptions had consequences for the city itself; the agreed-on assumptions necessitated the leasing of space to companies that would develop the city's technological solutions, rather than the sale of space to commercial or individual residents. Moreover, these cities would function as reference points for future smart city development. Thus, decisions made in the context of boundary object development were transformed from straightforward strategic issues (a choice of building materials, projections around financial figures) to arbiters between cognitive representations that promised to have lasting and important material consequences. The decisions became infused with significance: actors interpreted them as indications that the city that was emerging would not be the city they had imagined.

The Matter Battle Construct

I categorize the disagreements that characterized the development of boundary objects at SmartBlock and SmartTown as *matter battles*. The term matter battles was developed by an architect, who defined them as attempts "to execute the desires of the mind in any medium of physical matter" (Boyer, 2011). I propose that, in organizational settings, this term can be usefully applied to high-stakes conflicts about material outcomes.

My analysis suggests that matter battles can give rise to long-lasting, negative emotional and cognitive dynamics that fuel collaboration failure: profoundly negative emotions, and stereotyping and devaluation of others. Disagreements threatening actors' fundamental beliefs can give rise to strong negative emotions (Glynn, 2000; Maitlis & Ozcelik, 2004). At SmartBlock and SmartTown, because decisions reified cognitive representations into material outcomes, the conflicts evoked seemingly oversized bitterness, anger, frustration, and even contempt. Emotions powerfully shape attitudes: when negative emotions are directed toward other groups, individuals begin thinking about those groups by relying on simplifying stereotypes that emphasize the divisions between "us" and "them" (Fiol, Pratt, & O'Connor, 2009; Glynn, 2000). When conflicts are characterized by these negative emotional and cognitive responses, they can escalate into "an ongoing conflict spiral from which

FIGURE 2
Matter Battles, Boundary Objects, and the Failure of Collaboration



[individuals]. . .have trouble extricating themselves" (Fiol et al., 2009: 32). Rather than resolving their differences, SmartBlock and SmartTown actors thus formed simplifying stereotypes. Over time, they began limiting their interactions, disengaging from their mutual work, and even leaving the projects all together—thus stifling effective collaboration.

I propose that matter battles comprise a kind of intractable conflict. (Fiol et al., 2009). Intractable conflicts are "protracted and social conflicts that resist resolution" (Fiol et al., 2009: 33), and that are characterized by negative emotions, simplifying stereotypes, and the emergence of impenetrable barriers between different groups (Fiol et al., 2009). Prior research has suggested that when intractable conflicts emerge they cannot be solved through—and indeed, can be exacerbated by—typical methods of resolution (Fiol et al., 2009). Instead, they can set into motion emotional and cognitive dynamics that can preclude collaboration.

The literature has described intractable conflicts as enduring clashes between individuals from different ethnicities, nationalities, and societies that unfold over years and generations (Crocker, Hampson, & Aall, 2005). In organizational settings, they typically take the form of long-standing disputes between groups including workers and managers, physicians and administrators, artists and businesspeople (e.g., DiBenigno, 2018; Glynn, 2000). In contrast, matter battles occur among individuals without histories of prior clashes, who come together to create materiality amid ambiguity.

My findings thus suggest that intractable conflicts can arise not only because of long-standing divisions between different cultures and groups, but because of the escalating percolation of seemingly small breakdowns in the development of boundary objects. Intractable conflicts can therefore threaten any project that brings together diverse individuals working together to develop material outcomes in extremely novel settings.

Contribution to Research on Cross-Boundary Collaboration, Boundary Objects, and Innovation in Nascent Industries

By unpacking the process illustrated in Figure 2, this study contributes to the literatures on collaboration across boundaries, boundary objects, and innovation in nascent industries. Studies of collaboration across boundaries have typically identified boundary objects as tools of integration. Recent studies have recognized that some objects are insufficient as integrative mechanisms (Leonardi, 2011; Metiu & Rothbard, 2013; Seidel & O'Mahony, 2014). This study moves the literature further by suggesting that efforts to develop seemingly useful boundary objects can spark divisive conflicts that can be fatal for collaboration. Notably, the boundary objects described by the prior literature are typically used in mature, well-understood contexts, such as automobile development (Carlile, 2002, 2004), semiconductor manufacturing (Bechky, 2003a, 2003b), and architectural projects (Boland, Lyytinen, and Yoo, 2007). Although focused on a more nascent context—the development of new-to-the-world products—Seidel and O'Mahony's (2014) boundary objects were created in the context of a single, highly innovative firm comprising well-bounded teams of individuals with histories of prior joint success.

My findings suggest that the creation of boundary objects can spark conflict—and should be carefully managed—in projects and settings characterized by extreme novelty. These findings are likely to generalize to projects that involve new-to-the-world collaborations between actors who span firms and industries, particularly in nascent industries. Nascent industries comprise firms and projects that introduce products and services that are so radically different that they cannot be categorized as belonging to established industries (Benner & Tripsas, 2012). Like the actors developing SmartBlock and SmartTown, individuals in these settings lack precedents, and thus confront significant ambiguity (Aldrich & Fiol, 1994; Benner & Tripsas, 2012; Kaplan & Tripsas, 2008; McDonald & Eisenhardt, in press; Santos & Eisenhardt, 2009; Zuzul & Edmondson, 2017; Zuzul & Tripsas, in press). They can form different ideas about what their ventures should look like and how they should unfold (Battilana & Dorado, 2010; Jay, 2013; Vergne & Wry, 2014). Because they may be especially likely to fall prey to the destructive effects of matter battles, this study suggests that actors in these settings should take great care in managing the transformation of ambiguity into materiality.

Opportunities for Future Research

The purpose of this study was to generate, rather than test, theory. Nonetheless, my analysis provides evidence against several alternative explanations. For example, perhaps SmartBlock and SmartTown were poorly managed, or simply too large-scale and innovative, and therefore doomed to fail. However, as noted, both projects were launched by individuals with deep expertise in their respective fields; they brought together well-known and reputable architecture firms, urban engineering firms, and real-estate developers who were highly motivated to succeed in their shared efforts. In addition, the projects held strategic importance for all actors involved, were highly publicized by their organizations, and involved significant economic investments. To the actors involved, there was little inevitable about their failure; indeed, failure came as a surprise even to observers who had described them as leaders in the smart city industry.

My analysis also suggests ideas about boundary conditions that can be examined by further studies. For example, future research can attempt to explore the importance of leadership and power in driving and preventing matter battles. As noted, SmartBlock was led by a consortium of three organizations, while SmartTown was led by a single organization; it is therefore surprising that similar patterns replicated across both projects. My findings suggest that this may have occurred because, despite differences in leadership, neither project brought together actors who held the a priori or accepted power to set the vision for project development. Because they lacked templates or precedents for the development of smart cities, actors formed different ideas about whose contributions should be prioritized in development. Prior studies have shown that less powerful groups can influence more powerful ones by engaging in efforts to build support for their cognitive frames (Kaplan, 2008), and by drawing on their differences and dependencies (Howard-Grenville, 2007). However, in the case of SmartBlock and SmartTown, no set of actors believed themselves to be less powerful. Thus, they did not engage in these kinds of efforts, instead taking for granted that their ideas should be articulated, privileged, and prioritized. Future research can examine whether and how the dynamics I identify might replicate in settings with clearer leadership and more established power dynamics.

Future studies can also explore the role of expertise in generating matter battles. Research has suggested that, in novel settings that require the development of new ideas and logics, expertise and past success can hinder collaboration (Battilana & Dorado, 2010). As noted, partner selection at SmartBlock and SmartTown was based on histories of prior experience; the projects thus brought together groups of actors with deep expertise in their domains. These actors may have been especially likely to form strong cognitive representations, and to respond negatively to the prioritization of other actors' representations. An intriguing implication of this paper is that attempts to transform ambiguity into materiality may be especially dangerous for individuals with strong histories of success in established domains. These dynamics are reminiscent of research on competency traps (Levitt & March 1988; Tripsas & Gavetti, 2000) and threat-rigidity effects (Staw, Sandelands, & Dutton, 1981), whereby actors' histories manifest as a barrier to progress. Future research can explore whether and how these dynamics unfold in projects that bring together individuals with less expertise, who might be more flexible in their representations and ideas.

Finally, future research can attempt to explore the kinds of boundary objects that are especially likely to generate matter battles. The patterns I observed replicated across the creation of five boundary objects. Given similarities in the objects, as well as the common outcomes of these attempts, I was unable to examine whether and how specific features of different boundary objects made their development more or less problematic. For instance, all of the objects I studied required a great deal of specificity; that is, actors had to make highly specialized choices in order to move forward with their development. In addition, the objects had to be completed for each project to move toward the next phase of development. Finally, despite the novel nature of the projects, all of the objects were fairly standard in technology, sustainable development, and real-estate construction. Perhaps matter battles are less likely to occur around objects that provide more flexibility, that are not strictly required for progress, or that comprise more novel or innovative forms. Future studies can compare the creation of different kinds of boundary objects to further unpack variation in these and other elements that may be especially likely to lead to matter battles.

Overcoming Matter Battles

Perhaps the clearest opportunity for future research is the possibility to test opportunities for intervention that can prevent or pacify matter battles. Notably, the negative dynamics I identified were not resolved in either project, despite the projects' size, cost, and importance. This implies that developing emergent resolutions for matter battles is likely to be difficult. Perhaps one way leaders can avoid matter battles is by simply eliminating ambiguity from the start of a project, by setting out clear conceptual ideas and development processes. However, doing so may generate costs. Notably, in the early phases of SmartBlock and SmartTown's development, ambiguity was a positive feature: by allowing for a multitude of meanings, it drove excitement among a diverse group of collaborators. It is unlikely that these collaborators would have been equally motivated to work on a project that imposed a vision. This idea is supported by prior research suggesting that process underspecification can allow for experimentation, emergence, and innovation, and can motivate broad collaboration (e.g., Edmondson, 2012; Edmondson & Zuzul, 2016). Thus, while the early, imposed resolution of ambiguity may prevent battles, it might also stifle the motivation and creativity that are necessary elements of collaborative innovation.

Instead, my findings suggest that while ambiguity should not be avoided, its transformation into materiality should be closely managed. Diverse actors innovating in ambiguous settings should take care to integrate, or at least reveal, their cognitive representations. Individuals' knowledge structures are not impermeable; for example, prior research has suggested that actors can shift their frames by engaging with others who have different perspectives and points of view (Kaplan, 2008). I did not witness any changes in the cognitive representations at SmartBlock and SmartTown; nonetheless, future research can explore whether and how cognitive representations can be altered or combined. For example, future research could explore whether certain kinds of individuals are more likely to change their representations. This might build on research in hybrid organizations (Battilana & Dorado, 2010) showing that novices are more likely to embrace multiple logics than are experts. Large-scale innovation projects may not be able to rely on hiring novices, because their complexity calls for specific, expert knowledge. But perhaps, rather than selecting novices, the leaders of similar projects might consider fundamentally reconceptualizing their definition of expertise. For instance, rather than selecting based on prior histories of successful performance, they could select partners with prior histories of successful collaboration. Actors who are more experienced in collaborating across boundaries might be more likely to shift their cognitive representations, and avoid the perilous effects of matter battles.

Future research can also explore whether certain practices can successfully reveal and integrate representations. This study suggests that the development of boundary objects is uniquely capable of surfacing divergent representations. It is easy to agree on ideas while they are theoretical; when they become embedded in visible object choices, disagreements are likely. One way to harness the power of boundary objects while avoiding their perilous effects might be to work on a "pre-prototype": a draft boundary object with the sole, explicit purpose of surfacing different representations. If representations are surfaced without the high stakes that come with later objects, integration may be easier to achieve. I hope that future work will further explore these important challenges to benefit theory, and to help enable the success of innovative projects that call for collaboration across boundaries.

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