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The Future Isn't What It Used to Be: Anticipatory Organizing in the Digital Transformation of Water Infrastructure

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The Future Isn't What It Used to Be

Anticipatory Organizing in the Digital Transformation of Water Infrastructure

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Technology Management

by

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I am first indebted to my informants. I have developed such respect for the men and women who work often thanklessly behind the scenes maintaining our essential water infrastructure, especially during the COVID-19 pandemic. It is because of their work around the clock that we can turn on our taps and think nothing of it. Many of them would not mind and even prefer to be named here, but as this is an ethnography I am committed to the cover of anonymity. I am grateful for their stories, their trust in me, and also for their insights. I bounced ideas off of many of my informants when driving around in their trucks, drinking a beer together after work, and sitting alongside them when they wrestled with a spewing pipe. It is in part because of their own perspectives that I was able to produce this dissertation. I hope this research has been useful to them in some way.

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ABSTRACT

The Future Isn't What It Used to Be

Anticipatory Organizing in the Digital Transformation of Water Infrastructure

by

Virginia Leavell

This dissertation is organized around one central research question: How do organizations anticipate new technologies? I advance the thesis that technological anticipation shapes both structure and action in organizations long before the technologies themselves arrive on site. I provide support for this thesis through an ethnographic study of two organizations conducted over a three-year period before an expected technological change was to take place. In total I conducted over 830 hours of observations, more than 90 interviews, and nine surveys and collected more than 13,000 pages of documents. With my study of two water agencies that managed the production and distribution of drinking water, I show how field workers, office staff, and managers anticipated a new automated and digital metering system. I find that not only do people not need to interact with new technologies for the process of technologically induced organizational change to begin, but that the changes brought about, in part, by technological anticipation are themselves a significant phenomenon for the organizations that experience them. Specifically, I find that through the activities of information seeking, organizational action, and anticipatory control people in both

organizations developed changing predictions of their organizations' technological future. The predictions people held about their organizations' future states shaped action in ways that influenced not only the formal structures of the organizations themselves, but also the material qualities of the anticipated technologies. Consequently, I find that technological anticipation shapes the conditions under which technologies are selected, implemented, and eventually used by the adopting organizations.

These findings help us to reconsider the process of technologically induced organizational change. Importantly, I argue that predictions of probable futures actively shape work and organizing in the present. I also suggest that anticipatory organizing is likely to shape phenomena that occur much later. I present a model of anticipatory systems and urge scholars to consider the social and material implications of how actors imagine and predict technological futures in organizations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. Introduction

New technologies can upend work as industries and practices once taken for granted evolve and disappear. In organizations, tasks, routines, status, and business models rise and fall with the adoption of new technologies. Many lines of inquiry have led back to technology, in part because the study of technologically induced change has historically provided a means through which we have come to understand the structure, actions, and performance of organizations more generally (Perrow, 1967; Scott, 1990). Yet, despite the rich tradition of studying technological change in organizations, scholars have failed to appreciate the importance of technological anticipation. To anticipate is to "observe or practice in advance" (Oxford English Dictionary). Technological anticipation, therefore, is to observe and act in advance of an encounter with a new technology. We can apply the concept of anticipation to technology by asking whether organizational change depends on the material arrival of a new artifact, or instead if change can happen in advance of its adoption and implementation. It seems possible, and even likely, that people's predictions for the future can function as a trigger for action and restructuring. If this is true, it would mean that technologies' promises, and the hopes and fears that accompany their arrival, are an important part of the process of technologically induced organizational change.

If technological anticipation shapes structure and action earlier than implementation, understanding how anticipation may occur in organizations requires a reassessment of existing theories of technological change. Many of our explanations of the impact of technological change are based on studies of interactions with technologies during their implementation; for example, theories of structuration (Barley & Tolbert, 1997; Desanctis & Poole, 1994; Jones & Karsten, 2008; Orlikowski, 2000); deskilling (Attewell, 1987;

Braverman, 1998; Gallie, 1991); network effects (Burkhardt & Brass, 1990; Levina & Vaast, 2005; Rice & Aydin, 1991); and technological framing (Fayard et al., 2016; Leonardi, 2010; Orlikowski & Gash, 1994), among others. How do these phenomena function in *advance* of adoption and implementation, if at all?

That we have not asked the question of how organizations may change in advance of implementation is curious for two reasons. First, there is evidence in the empirical record of technologically induced organizational change that suggests anticipatory organizing is likely taking place, but those data have not been theorized in relationship to people's understanding and anticipation of a coming change. Rather, scholars have theorized action in advance of implementation in relationship only to what happens after, passing over the potentially anticipatory nature of pre-implementation activities. Studies that directly consider activity in advance of implementation (i.e., Noble, 1984; Shestakofsky, 2017; Thomas, 1994) consider the "before" data as background for the change on which their work is focused. For Noble (1984), information about work before the introduction of numerical control automation is important in that it provides an explanatory contrast in how machinists worked before engineers installed the technologies. Noble's core argument was that there is more than one way to adopt automation technology in a firm, but that managers prefer technologies that remove decisions and high skill tasks from the floor and relocate them in the engineers' offices. Data from before the change provide a baseline status against which change can be measured. Similarly and more recently Bailey, Leonardi, and Barley (2012) analyzed the "pre CAD period" as a contrast to what came later, for example "before the arrival of CAD, all roles in engineering depended heavily on and had good access to vehicle parts," or "before CAD, parts engineers and drafters used physical parts" (p. 1492). Scholars have not considered anticipatory action as a phenomenon distinct from post-implementation effects of technologies. To understand anticipation, we need studies of it as a distinct phenomenon free from the role of providing a contrast to the "real" change that comes later.

A second reason to study anticipation is that it is clear from the literature on agency (Emirbayer & Mische, 1998), sensemaking (Gioia et al., 2002; Weick, 1995), and planning (Das, 1987; Weick, 1990) that actors can and do act on receipt of advanced information about coming changes before the expected change takes place, if that change even takes place at all. While it is clear that scholars continue to agree that "structures of organizations and occupations are related to the technologies they employ," there is less clarity about when and where this relationship may begin (Barley, 1990a, p. 61). People are likely to anticipate technological change because their futures will be shaped by the disruptions, opportunities, and affordances that will accompany it. Many hopes and anxieties accompany expectations of technological change (Turkle, 2007). Information about new technologies can reach and impact people in organizations long before the arrival of technologies themselves. What are we missing when we do not study organizational change on the basis of advanced information about new technologies? For example, instead of studying the impact of automated vehicles only at cities where they are already deployed, researchers might instead look to communities that have only *heard* about driverless cars. Researchers could ask whether in these communities the relevant government bodies are reassessing their traffic laws (Greenblatt, 2016). Are highway administrations directing funds to upgrade highways and roads for humans, or have they instead made accommodations for self-driving cars (Oliver et al., 2018)? Are consumers holding off on purchasing their next vehicle until self-driving technologies are more widely available? We cannot answer questions like these because we know neither how actors develop predictions of technological change nor the consequences of anticipatory action.

In this dissertation, I explore how people in organizations anticipated technological change. I conducted a study of two which I call “Fogtown” and “Suntown” - managed water infrastructure in comparably sized cities, and at the time of the study both were just beginning to plan a major digital transformation in how they managed drinking water. As I will show in the following sections, it is important to understand both the predictive processes in organizations and the way in which predictions influence action. Because anticipation is expressed through action, this study has a particular focus on actions that people took in organizations and the ways in which those actions were explained, justified, and defended in the context of coming technological change. I first review the existing literature on technologically induced organizational change and theorize the limitations of a reactive, post-implementation research paradigm. I then theorize the phenomenon of anticipation as informed by both the organizational literature on sensemaking and the theoretical biological literature on anticipatory systems.

Evidence of Anticipation of Technological Change

Changes made in advance of technological change are likely to impact later periods of selection, implementation, and use. Anticipatory activity in early stages alters the structure of work and meaning into which the new technology is adopted (Orlikowski, 1998). How, for example, would a workgroup with a pessimistic outlook select for a technology in contrast to one with an optimistic expectation? One limitation to understanding technological anticipation is that scholars have treated implementation as the starting gun of the organizational change process. Studies of technologically induced organizational change have favored analyses of reactions to material artifacts. This means that by convention, students of technology, organizations, and work mark the beginning of the organizational change process only with the material arrival of a technology, for example when the technology lands on an organization's receiving dock or is downloaded by employees, as in the case of financial firms adjusting to new algorithmic trading programs (Anthony, 2021; Beunza & Stark, 2008), organizations adopting a new enterprise resource program (ERP) (Boudreau & Robey, 2005), or teams beginning work on a new simulation software (Dodgson et al., 2007; Leonardi, 2012a). Consequently, scholars have limited their research by looking for the effects of new technologies only after organizations have begun to implement a technology. Without an appreciation of the effects of anticipation, we miss out on a potentially critical set of processes driving technological change that could complicate our current understanding of the phenomenon.

Although technological anticipation is likely a factor in many kinds of change processes, it seems particularly important in the process of digital transformation. Digital transformation is a complex and far-reaching process that affects organizations in substantial ways that are different, or at minimum, more extensive than prior experiences of digitization and digitalization (Vial, 2019). Comparing definitions of the three kinds of digital change is useful for understanding how digital transformation is different than other change processes. *Digitization* is the "conversion of mainly analog information into the binary language understood by computers," a process that began with the adoption of new computer technologies in the 1950s (Hinings et al., 2018, p. 52). *Digitalization* goes further to include the production of novel data outputs that are distributed across new structures of communication (Leonardi & Treem, 2020; Verhoef et al., 2021). While there are some disagreements and related definitional gray areas between these two definitions and others I have left out,[1] there is a broad consensus that the difference between digital processes in the past and the case of digital transformation today is a matter of complexity and reach. The definition of *digital transformation* is much more expansive than the others, in that it is fundamentally about both system-wide and institutional change, not just changes in work practices. Digital transformation is the:

> …combined effects of several digital innovations bringing about novel actors (and actor constellations), structures, practices, values, and beliefs that change, threaten, replace or complement existing rules of the game within organizations, ecosystems, industries or fields. (Hinings et al., 2018)

Digital transformation subsumes digitization and digitalization (Verhoef et al., 2021).

Because digital transformation has affected a great diversity of organizations in multiple industries (Hess et al., 2016), news of the technologies and their impacts will likely have reached organizations long before they begin to undertake the transformation, if they even attempt it at all. Industry experts advise that digital transformation will potentially "trigger disaster" and require that business models be abandoned or redrafted (Downes & Nunes, 2013). Practitioners advise the need for advanced preparation and strategizing before implementing technologies that will trigger digital transformation (Alstyne & Parker, 2021; Smith, 2021). Sometimes firms make major moves before technologies are in place. The recent announcement of Facebook's rebranding to Meta and related reorganization, for example, was based entirely on a technology called the "metaverse" that does not yet exist (Roose, 2021). Metaverse hopefuls are buying digital land and hiring new staff in

[1] The terms "datafication" and "informating" have been used to describe much the same processes as that of digitalization, and for the sake of clarity I am restricting the discussion to only three terms: "digitization," "digitalization," and "digital transformation" (Leonardi & Treem, 2020; Zuboff, 1988).

anticipation that the metaverse will be a place where they will do business in the future (Dilella & Day, 2022).

When scholarship on technological change includes evidence of action in advance of implementation it is often a consequence of a before-and-after research design. Researchers have tended to focus on structural aspects of organizations before the change so as to highlight how they differ from structures that emerged after implementation. In other words, if agency is considered it only appears during implementation and use. Most studies of technologically induced change begin data collection after the technology has been implemented (Barrett et al., 2012; Brayne, 2017; Pachidi et al., 2020). Organizations scholars have understood change studies to be ideally longitudinal, so as to "catch reality in flight" and derive insights from observations of the effects of the change (Pettigrew, 1990, p. 270). A survey of representational examples of technologically induced organizational change studies is in Table 1.1.

Table 1.1

Studies of Technologically Induced Organizational Change

Study	RQ	Technology and site	Primary data	Findings	Action in advance of technological change?
Anthony, C. (2021). When knowledge work and analytical technologies collide: The practices and consequences of black boxing algorithmic technologies. *Administrative Science Quarterly*.	How and why might expert knowledge workers come to trust their analytical technologies without understanding how they work?	Two new algorithmic tools (Factset & CapIQ) that gather financial data from public filings and automatically populate numbers into spreadsheets.	Observations & interviews over two-year period after introduction of new technology & archival data.	Junior bankers no longer had to compile financial data themselves. One group understood the algorithm, the other did not. Senior bankers changed by holding junior bankers to higher standard so that they would understand the process behind the technology.	NA
Bailey, D. E., Leonardi, P. M., & Barley, S. R. (2012). The lure of the virtual. *Organization Science*, *23*(5), 1485–1504.	What happens when new digital technologies facilitate operating with, on, and within representations of physical entities, as well as the transmission of these representations across great distances.	Virtual work of auto engineers in two countries around use of crash test simulation program.	Observations and interviews over three- year period post implementation of virtual technologies.	Simulation technologies can engender changes in the work structure as well as in tasks and roles.	"Pre digital" phase included with retrospective interview data, but analysis limited to basis of comparison for after technology arrives.
Barley, S. R. (1986). Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments. *Administrative Science Quarterly*, 78–108.	How does technology shape organizational structure?	CT scanner at two hospitals' radiology departments.	Observations and interviews beginning with adoption of CT scanners.	Technology occasions changes to structure. Outcomes depend both on the materiality of the technology and the historical processes in which they are embedded.	Training sessions for staff.

Boudreau, M. C., & Robey, D. 2005. Enacting integrated information technology: A human agency perspective. *Organization Science, 16*(1), 3–18.	What is the role of human agency in shaping the enactments of an integrated computer based, enterprise information system after its implementation?	ERP system at large government agency.	Observations and interviews beginning at ERP implementation.	A period of inertia was followed by a period of reinvention. Users exercised considerable discretion in their use of an integrated application of information technology.	"Project leaders understood that each modification [to the ERP software they were acquiring] would require extra work during implementation and complicate future upgrades, so they consciously minimized the number of modifications to the package." & "Formal training sessions were made available a few months prior to the rollout date" (pp. 8–9).
Brayne, S., & Christin, A. (2021). Technologies of crime prediction: The reception of algorithms in policing and criminal courts. *Social Problems, 68*(3), 608–624.	To what extent does the adoption of predictive algorithms affect work practices in policing and criminal courts? How do practitioners respond to algorithmic technologies (i.e., do they embrace or contest them)?	Introduction of predictive algorithms to policing and criminal justice organizations.	Observations and interviews after implementation of predictive tools.	Widespread use of predictive technologies, which are trusted more than "intuition." Resistance to technologies is also widespread.	Indication of "objectivity" and "efficiency" framing and justification, but no explanation of how actors arrived at justifications for adoption.
Dodgson, M., Gann, D. M., & Phillips, N. (2013). Organizational learning and the technology of foolishness: The case of virtual worlds at IBM. *Organization Science, 24*(5), 1358–1376.	How and why is organizational learning facilitated by virtualization technologies?	Virtualization technologies the use of virtual worlds (Second Life) at IBM.	2.5 years of interviews & observation at IBM after use of virtual worlds was established.	Virtual worlds encourage learning through play.	Development of a virtual world strategy document in advance of use.
Edmondson, A. C., Bohmer, R. M., & Pisano, G. P. (2001). Disrupted routines: Team learning and new technology implementation in hospitals. *Administrative Science Quarterly, 46*(4), 685–716.	How are new routines are developed in organizations in which existing routines are reinforced by the technological and organizational context?	New minimally invasive cardiac surgery technology at 16 hospitals.	Interview and clinical data post-implementation.	The new technology changes individual team members' tasks, blurs role boundaries and increases team interdependence. Variance in implementation success.	First steps in implementation process: "Enrollment" (leaders action or careful selection of team members) and "Preparation" (leader's actions or offline practice session). Actors engaged in discussions, literature reviews, planning for worst case scenarios, watch films. Prediction mentioned of "complete restructuring."

Majchrzak, A., Rice, R. E., Malhotra, A., King, N., & Ba, S. (2000). Technology adaptation: The case of a computer-supported inter-organizational virtual team. *MIS Quarterly*, 569–600.	Can the workgroup adapt any or all structures, or does it primarily try to adapt to the technology's initial spirit? Do pre-existing structures constrain the workgroup's adaptation process, even when these structures are malleable?	Use of new collaborative technology by virtual team during product development.	10 months of observations & interviews of newly established virtual team, weekly questionnaires.	Virtual team adapted structure multiple times to better fit technology.	Analysis of interview data produced analysis of "pre-existing structures for each team member, i.e., how the team members would typically design a new product for their companies" through interviews" and mention of intention to keep asynchronous work structure.
Pachidi, S., Berends, H., Faraj, S., & Huysman, M. (2021). Make way for the algorithms: Symbolic actions and change in a regime of knowing. *Organization Science*, *32*(1), 18–41.	How do actors' struggles unfold and lead to radical changes in knowing practices?	Introduction of algorithmic data analytics technology to support sales activities in large telecommunications firm.	24 months of observations and interviews after implementation of technology.	Both the technologists who introduced the algorithmic technology, and the incumbent workers whose work was affected by the change, used symbolic actions to either defend the established regime of knowing or to advocate a radical change.	Data scientists within firm "acted as the champions of data analytics and extolled its potential to revolutionize the operations of both marketing and sales."
Vaast, E., & Walsham, G. (2005). Representations and Actions: The Transformation of Work Practices with IT Use. *Information and Organization*, *15*, 65–89.	How exactly do work practices change with IT use?	Introduction of intranet in a French insurance office.	Observations, interviews and focus groups.	Agents interact in ways that are consonant, not dissonant, with preexisting work environment.	Decision to implement intranet followed by internal development of technology and 6 months deployment. No discussion of other actors' activity in relation to intranet despite its being developed on site over an extended period of time.

What this table reveals is that the effects of technological change are far reaching and that similar activities can produce diverse outcomes. Implementation processes involve many people and they can meet resistance and even sabotage by the technologies' intended users in extreme cases (Brayne & Christin, 2021; Pachidi et al., 2020), and in other cases they can blur tasks and boundaries between roles in ways that reshape how groups function (Edmondson et al., 2001). Implementation can take time as people cycle through multiple adaptive processes to bring use in line with earlier forms of work (Majchrzak et al., 2000; Vaast & Walsham, 2005). If there are many similar phenomena at work in technological change processes, could they have different outcomes in part because of anticipatory activities in an organization's pre-implementation past?

Studies have demonstrated a tendency to "left censor" (Leonardi & Barley, 2010) the change process. Leonardi and Barley (2010) argued that researchers almost always:

> …[begin] research after adoption, thereby divorcing implementation and use from preceding decisions and events. When studies begin with little insight into why technologies were designed as they were, why one technology was chosen over another, or how the technology was deployed, they essentially left censor the construction process. The tendency to left censor makes it impossible to determine whether patterns of use are shaped in important ways by dynamics of power, control, status, and conflict that set the context of use. (p. 39)

Without explicitly calling for studies of anticipation, Leonardi and Barley made a case for it by describing the consequences of left censoring as limiting studies of organizations that undergo change. Instead of presuming that questions about pre-adoption process can be answered by studying design, in this proposal I suggest that we might instead look to the construction process in the *adopting* organization. Furthermore, what the sixth column in Table 1.1 shows is that sometimes studies *do* uncover evidence of anticipation, but they confine its analysis to a basis from which to compare later structural change in the organization with the adoption of a new technology.

Two studies are representative of an approach that considers pre-implementation data absent an accounting of anticipation. Beane (2019), for example characterized trainee learning in communities of practice before the arrival of surgical robots as a matter of “direct and increasing participation in experts’ work,” while learning practices after the implementation of the robot required deviant “shadow learning” and premature specialization (p. 88). It appears that work practices remain unchanged until the arrival of the machine, as Beane’s analysis used implementation as a threshold after which deviant behavior began, which he contrasted with the untouched pre-implementation period. Similarly, Orlikowski and Scott (2014) contributed to ideas about organizations and valuation with their findings that the introduction of online evaluation tools into the hotel industry brought about significant changes in work practices and valuation activities. Before hotels had TripAdvisor profiles, practices of valuation were explicit and governed by an organization that produced a reference guide. The initial conditions of hotels were such that managers could reliably predict their valuation based on transparent criteria over which they had some control. In contrast, after valuation went online, hotel staff adapted by managing the review process at the moment of guest contact, organizing weekly meetings to assess online reviews, but still struggled to understand the opaque, proprietary TripAdvisor valuation algorithm. The research design of these and similar studies captured data before the arrival of a new technology, but people’s perceptions of the implications of change in advance of adoption were overshadowed by the findings of what came after.

The sixth column in Table 1.1 gives examples of data captured in organizations before technological change that suggest the presence of anticipatory action. Scholars often capture data about pre-implementation organizational activity whether by being on site or drawing from ethnographic interviews. Intended to provide a basis upon which to analyze and theorize technological change, research designs sometimes include data not only of post-implementation, but also data collected before of the adoption of a new technology (Barley, 1990b). At times, authors have included examples of anticipatory action in an offhanded way, but they included pre-implementation data only to provide a contrast with post-implementation consequences. They have mentioned the example and often included excerpts from interviews or observations, but they have not focused on it. An especially revealing additional example is Leonardi’s (2011) study of the adoption of a computer simulation for crashworthiness engineering work at a major automaker. Engineers in the firm’s R&D department worked for 10 years to develop a simulation tool for crash testing. Before building the tool, the work of crash testing was both labor intensive and expensive as engineers had to physically crash a test vehicle in a lab and use data from the physical tests to build iterative simulation models to analyze performance and make predictions. The goal of the new tool, called CrashLab, was to reduce this time and effort by producing a simulation tool that could make predictions without needing to crash a physical vehicle or build a new model from the data each time. While Leonardi marked the start of the change process in September 2005 when the tool “was deployed into the user community,” he included evidence that suggested changes had already begun to take place (p. 156). One engineer reported:

> The problem that I and some others had with CrashLab was that, I mean, at that time we didn’t even have anything standardized.... If we are ever going to have math

> [simulations] lead the design and reduce our reliance on physical testing, we had to standardize the way we do the simulation work.... And the whole question of quality and accuracy of the results is what drove us to know that the engineers had to start doing the work the same way. (p. 159)

The engineer in this quote described how engineers began to align their work practices *in advance* of adopting the new tool, so as to ensure the tool could be useful across different teams. Leonardi himself summed up the activity, pointing out that "Before CrashLab could automate standard work procedures, Autoworks needed to define what those standard work procedures were" (p. 159). This suggests that engineers engaged in a process of standardizing their work practices in anticipation of using a tool that did not yet exist. Through some means unexplained in the study engineers arrived at a prediction that the tool could be built and would benefit their work if they aligned work practices in advance. What information did engineers use to make this prediction? How did alignment activities affect their work and their predictions? Was there discord among workgroups about alignment activities about which work practices would become standard? Such questions are not typically answered within studies of before-and-after technological change in organizations.

The only area in which organizational change is studied in advance of implementation is in the context of design. These studies are revealing, but less useful because scholars have looked *away* from the receiving organization and instead to *different* organizations that design new technologies (Bechky, 2003). Where existing research has been unable to answer key questions, scholars have pushed for studies to target processes *before* design during conceptualization or *after* organizational adoption for institutional effects (Bailey & Barley, 2020). Other studies of organizational change during the design process are similarly reliant on the presence of the material technology to explain structure and action, for example as the basis of communication across occupations (Bechky, 2003). Instead of looking to separate firms in hope of explaining the effects of technologies on organizations, we should instead deepen our study of the receiving organizations to understand the way in which they anticipate change and its effects on their work and the larger organization. I theorize this turn in the next section.

Theorizing Technological Anticipation

Anticipation is not a new concept in the study of organizations. Weick (1979) considered actions and anticipatory effects when he argued that the true purpose of predictive planning had little to do with whether plans were ever realized. Rather, the ways in which people predict and plan for the future:

> …become *excuses for interaction* in the sense that they induce conversations among diverse populations about projects that may have been low-priority items. The interaction may yield immediate positive results, but such outcomes are usually incidental. Much of the power of planning is explained by the people that it puts into contact and the information that these people exchange about *current* circumstances. (Weick, 1979, p. 11[2])

Weick's description of the future began to theorize it as shaping the present. Future outcomes are less important than the impact of future thinking on organizing. In one sense, incorporating information and experience from the past and present into ideas about the future is a fundamental quality of human agency, and as such it is a reoccurring process that guides actions in the present (Emirbayer & Mische, 1998; Pontikes & Rindova, 2020). Emirbayer and Miche (1998) explained the relationship of the future to agency with the concept of "projectivity," or the "imaginative generation by actors of possible future trajectories of action, in which received structures of thought and action may be creatively reconfigured in relation to actors' hopes, fears, and desires for the future" (p. 971).

[2] Emphasis added by author.

Agentically, the future becomes relevant in the present through decisions and actions that are informed by information and ideas *about* the future. Recent theories of firm strategy (Rindova & Martins, 2021) have begun to incorporate ideas similar to Weick's to understand how ideas about the future shape action in the present by influencing interactions and decision making in the present: "futurescapes …are intended to shape beliefs about the future in relation to the focal firm's distinctive resources, capabilities, and strategic intentions" (2021, p. 12). Future thinking plus action make up essential parts of an anticipatory system.

The mechanisms with which people incorporate the future into present action are diverse. The future occupies a permanent state of "ontological non-existence" that people access through language, sensemaking, and narrative (Rindova & Martins, 2021, p. 17). Flyverbom and Garsten (2021) introduced the concept of "temporal reorganization" as a means by which actors cope with the future. They coined the term "anticipatory governance" to describe a "performative phenomenon that addresses potential and desirable futures and operates as a mode of shaping, controlling and orchestrating organizations" (p. 3). They argued that organizations employ anticipatory governance to bring the future in the present. This matters in organizations because, they argued, power over future projections is a form of consequential knowledge production, such that anticipation has "organizing effects" in the present (p. 2). In addition to making future projections, another means of reaching beyond the present and into the past or future is through narrative.

Narratives can extend a temporal horizon to connect the near and distant future to action in the present (Bartel & Garud, 2009). Narratives told in the future perfect (i.e., "the project will have succeeded") give actors "the capacity to see in a thing what it is not, to see it other than it is" (Weick, 1979). These mechanisms may be at work in organizations as they anticipate technological change, enabling a future technology to shape the present long before its implementation (Alvial-Palavicino, 2016). Gioia, Corley, and Fabbri (2002) argued that to even make sense of the future, people have to place it in the past by talking about it the future perfect tense (i.e., "will have happened"): "people envision a desired or expected future event and then act as if that event had already transpired, thus enabling a 'retrospective' interpretation of the imagined event" (p. 623). Anticipation is a quality of organizing such that actors work to manage future events by narrating and shaping the present. Anticipation brings together past experiences and future projections into present tense activity that affects events such that they "occur earlier [or] advance in time" (Oxford English Dictionary, "anticipate") Barley (2015) introduced the idea of "anticipatory work," which analyzes the future-oriented thinking of weather scientists in modeling work. Barley did not actually define the word "anticipation," assuming the definition is self-evident. He evidenced anticipatory work in the "the process by which scientists at NCAR anticipated their partners' representational needs and produced data representations that would meet those needs" (p. 1613). Barley extended the theory of performativity to explain the ways in which scientists limited their scope, and even abandon an important scientific discovery, to facilitate others' future impressions of their modeling representations. Anticipation for Barley was the work of shaping future impressions of others. How the scientists came to understand a particular future as probable, or what the relationship was between the future and the present, is still unknown.

We need a model of anticipatory action that could guide an analysis of an organizational system. One model that could support organizational theorizing of anticipation is the biological theory of anticipatory systems. I turn now to how anticipatory systems theory can help to both extend and make more specific our current theorizing on anticipation in organizations. I summarize the theory's basic structure and propose the adoption of several of its constructs before identifying an area of technological change most appropriate for the study of anticipatory organizing.

Anticipatory Systems Theory for the Study of Organizations. The biological theory of anticipation is existential. It posits that organisms must anticipate to survive, such that the decline of an organism's anticipatory capacity parallels the decline of other abilities during the aging process (Nadin & Naz, 2021). Rosen (2012) defined an anticipatory system as any system "in which present change of state depends on future circumstances, rather than merely on the past or present" (p. v). The theory points to evidence of anticipatory action in the world whenever an organism acts on information about a probable future that has not yet arrived.

I have borrowed anticipatory systems theory (AST) from theoretical biology for my study of technologically induced organizational change for two reasons. First, the theory provides a way of incorporating predictions of the future into organizational action at the level of an organizational system. For biologists, that system has been an organism (Mazzocchi, 2012). Modified for organizations, AST avoids relying on microlevel theories of cognition (Bera et al., 2019) that have been developed from the study of individuals or of small groups. While individual ways of knowing, perceiving, and acting are important within any organizational analysis, in this dissertation I ultimately want to know how *organizations* anticipate new technologies. AST contributes to a sociomaterial (Cecez-Kecmanovic et al., 2014; Leonardi, 2013b; Orlikowski, 2007) and sociotechnical systems (Hughes, 2012) approach.

The second reason is that AST distinguishes between predictions of a future *event* and predictions of a future *state* in explaining how predictions of the future shape a system in the *present.* Anticipating new technology in organizations involves the development of predictions and related action. Studies of performativity, for example, have centered around predictions of an event, like a price of a particular stock (Beunza & Stark, 2008; MacKenzie, 2006), or a presentation to colleagues (Barley, 2015). Studies of strategic planning have considered the total system of an organization based on a series of contingencies (Hickson et al., 1971) or goals (Ketokivi & Castañer, 2004), but we do not know how the development of strategic plans and predictions recursively shape structure and action within the organization itself in advance of whether the predicted events come about, if they do at all. To study anticipation is in many ways to forgo the punchline of a story. Some readers may be surprised that in this dissertation I do not explain what eventually happens at either of the organizations I studied. Whether either successfully later implemented and used technologies is wholly irrelevant to the study of anticipation. What is important is how predictions of probable futures shape work and material infrastructure long before the expected state of an AMI organization comes about. AST provides a structure through which to analyze these events.

Rosen (2012) theorized anticipation as a system in which the future is a causal agent:

> Living organisms have the equivalent of one "foot" in the past, the other in the future, and the whole system hovers, moment by moment, in the present—always on the move, through time. The truth is that the future represents as powerful a causal force on current behavior as the past does, for all living things. (p. xii)

Anticipation is always expressed through action. Action distinguishes anticipation from the related processes of prediction. Expectation is an internal, cognitive state limited to *looking forward* to a future event. Anticipation is an externalized, social event that involves action taken in advance of a probable future occurrence. The analytic purchase this distinction avails to a student of organizations is a framework in which we can distinguish 1) what is expected (or predicted), 2) how this expectation was developed socially within the organization, and 3) what actions are shaped by expectations at the level of the organization. Expectation's shaping of action makes up the basic phenomenon of anticipation. In a general sense, anticipation is any action that follows from a prediction.

Both Rosen and Nadin theorized an anticipatory system as having three key components within an environment, which are depicted in Figure 1.1:

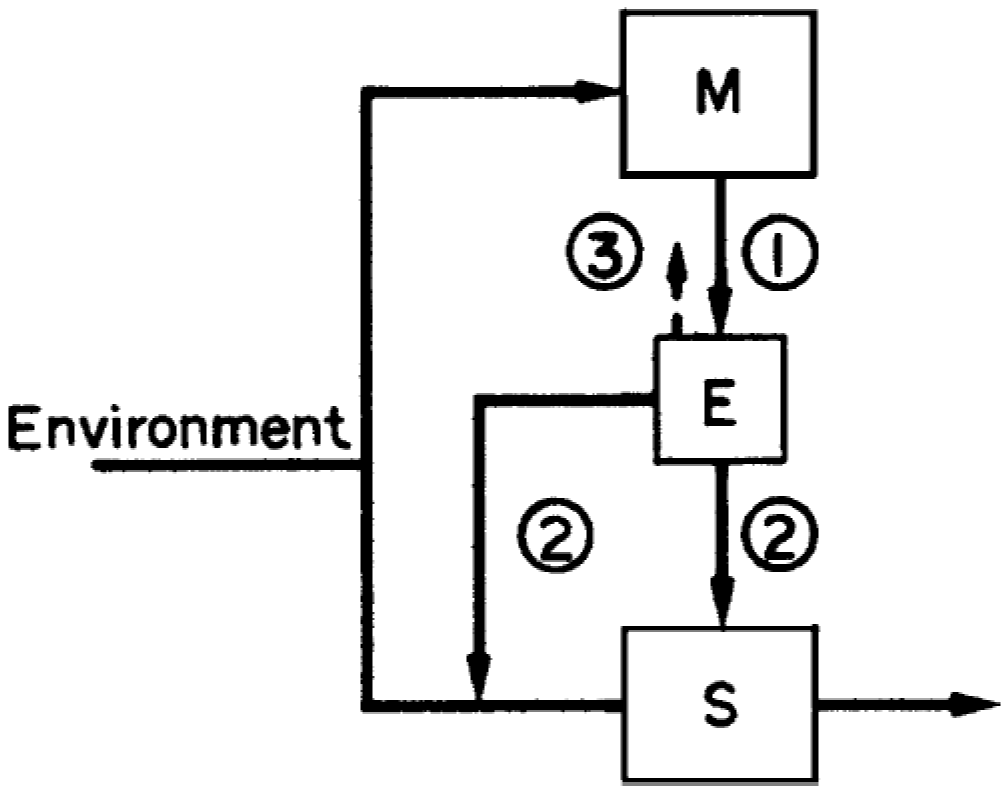

Figure 1.1. An Anticipatory System (Rosen, 2012). M is a predictive model of the system (S). E is the effector system, or actions taken to influence S on the basis of M.

First is the system itself ("S"), which is any "natural" system with definable boundaries, like a galaxy, a lake, or a meadow. Natural systems are in the present. They are complete and complex, and "always incompletely known" (Rosen, 2012, p. 45). A second component is a formal, predictive model of the natural system, presented in Figure 1.1 as "M." Formal systems are semiotic representations of some limited aspects of natural systems. An example of a formal model of a system can be as simple as "winter is coming and my water source will freeze." Unlike a simulation, the purpose of a model is not to replicate the referent system as completely as possible, but rather to represent it for the purpose of testing hypotheses or demonstrating the relationships among a system's elements. Anticipatory Systems Theory posits that actors maintain predictive models of their natural system by incorporating information from the past, the present, and the surrounding environment. A third component emerges from the model M as a set of effectors, "E," which operate on the system itself, or on the environmental inputs to the System, "S." Effectors are informed by the predictive model. If the predictive model is negative, effectors are actions that change either the surrounding environment or the system itself such that action could bring about a more preferable future state. If the prediction is positive, effectors will maintain the current system trajectory. An example of an effector is as simple as the act of migrating south to a warmer climate or hibernating until spring. Because predictive models are not complete, effectors can produce unexpected side effects, as shown by the right-angled arrows in Figure 1.1. A migration may be thwarted by power lines, or hibernation by a natural disaster.

Each of these three components, the natural system, an actor's predictive model of that system, and effector actions, are connected through inferential feedback loops. An actor incorporates consequences of effectors into the formal predictive model such that it may better inform action moving forward. New information from the environment can help an actor better distinguish between the many possible futures to a smaller set of more probable futures, which can in turn inform action. As I will show in subsequent chapters, inferential feedback loops in organizations like water agencies shaped the kinds of predictions people in those organizations made about a coming technology. Information about a future technology reached people within the organization, who then incorporated the prediction into their own actions. Their actions influenced subsequent predictions, producing a trajectory of anticipatory action. I will show how when a project stalled out at one agency, inferential feedback loops were curtailed and predictions remained narrow in scope. In contrast, at the agency where the project received support from upper-level management, inferential feedback loops continued to cycle between prediction and action such that the prediction was much more expansive in its scope of application.

In anticipatory systems, there is an inferential modeling relation between the system and its formal model. The formal system should be consistent enough with the natural system that actors can make predictions from it. This is done through a process of encoding (observation and measurement) and decoding (predicting). If inferential hypotheses are correct, a prediction proves to be accurate. Whitehead and Griffin (1985) described how the known environment is incorporated into anticipatory inference:

> For the organic philosophy anticipations as to the future of a piece of rock presuppose an environment with the type of order which that piece of rock requires. Thus the completely unknown environment never enters into an inductive judgment. The induction is about the statistical probabilities of this environment. (p. 205)

What they were saying was that knowledge about the environment is essential to the process of anticipation. When someone knows nothing about the environment, it is difficult to anticipate what probable futures lie ahead. But when someone knows a great deal about the environment, then his or her perceptions of the future may be more aligned with what will most probably occur. Thus, an inability to account for unknown environments in part explains why actors cannot anticipate and adapt to changes that fall outside of their environmental presuppositions. Within the realm of the known environment, however, if a prediction does not bear out, this outcome entails further encoding and adjustments to the formal system. Rosen's (2012) figure of the modeling relation, shown in Figure 1.2, depicted this process.

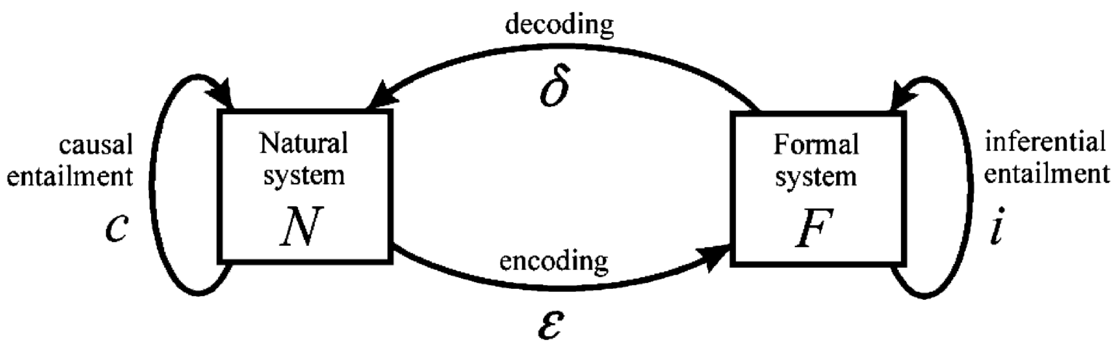

Figure 1.2. The Relationship Between the Model and the System (Rosen, 2012).

From the formal system one can make inferences about how the natural system might behave. What is important about the inferential modeling relation is that it expresses a way in which organisms interact with the world around them and make predictions in order to survive. At its most basic interpretation, anticipation is about an actor having a sense of how the world works and using information from the environment and from action to continually reassess how that actor understands the world and their place in it. In other words, causal entailment feeds the encoding process in the formal system.

Anticipatory systems are not deterministic. They are only probable. Like any natural system, the organization and its environment are complex systems, and action does not always have the planned effects. No model of a social system can capture all potentialities. Instead, there are “side effects,” or unforeseen consequences. These are modeled as the arrows #2 in the overall model. Rosen included a dotted arrow (3) from the effector system back to the model (M) such that the consequences of actions serve as further inputs back into the predictive model (Rosen, 2012, p. 14).

As students of organizations, we can do two things differently by applying AST to the study of technological anticipation. These are the application of the AST constructs of *surrogate time modeling* and *feedforward control*. Both are useful in explaining how probable futures shape structure and action in the present, and how actors shape not only what is possible within the organization, but what it is possible to predict at all.

Surrogate Time Modeling. Surrogate time modeling is useful to students of organizations because it reframes our analysis from prediction as an activity that becomes meaningful in the future to prediction as an activity that is consequential in the present. In an anticipatory system, actors develop internally predictive models that incorporate information from the past, the present system, and the outside environment to make predictions about a system’s future state. An important quality of anticipatory models is their basis in an *internal surrogate of time*. By “surrogate” anticipatory systems, theorists mean that the model runs *faster than real time* to produce predictions about changes in the present state:

> With S we shall associate another dynamical system M, which is in some sense a model of S. We require, however, that if the trajectories of S are parameterized by real time, then the corresponding trajectories of M are parameterized by a time variable which goes faster than real time. That is, if S and M are started out at time T 0 in equivalent states, and if (real) time is allowed to run for a fixed interval T, then M will have proceeded further along its trajectory than S. In this way, the behavior of M predicts the behavior of S; by looking at the state of M at time T, we get information about the state that S will be in at some time later than T. (Rosen, 2012, p. 12)

Rosen's concept of modeling and time scales has posited that actors continually maintain a predictive model, and that this model parametrizes time on faster intervals than experienced by the actor in the natural system. The presence of a model of the system at a future state in time enables that model to inform activities in the present. This means that predictions are not isolated events that take place at a single point in time in a conversation or planning session, but instead are continually produced and modified by an actor. Like modeling in other contexts, the "degrees of freedom in internal models allow time its multi-scaling and reversibility to produce new information" (Louie, 2010, p. 20). Models are an essential component of anticipatory systems in that actors can mentally project into the near or distant future, or run information about a future event backwards to estimate its relevance.

Predictions are an important organizational activity, but we typically assess a prediction on the basis of its outcome. Studies ask whether a prediction about which candidates would do well in a job interview bore out in practice (O'Brien & Kiviat, 2018), or whether data about consumer trends accurately predicted which products would sell best in a particular timeframe (Agarwal et al., 2018). AST draws our attention away from the outcome and focuses on the present. Surrogate time modeling positions predictions as meaningful *only in relation to their shaping the activity and structure of the present state system*. The theory posits that new information from the environment does not inform action because actors *react* to it, but rather because actors incorporate new information into the model of their system. Information is an input to a formal model, which represents the current state in a probable future that incorporates the effects of the new input. Surrogate time modeling suggests that we cannot fully understand action without understanding the predictive model of the system in which it takes place. Applying the construct to organizations, we can posit that actors produce and maintain internally predictive models of their own organizations. Actors can and do participate in formal planning processes and use digital technologies to make detailed and explicit predictions, but in an anticipatory system we would expect the formal model to be more expansive and possibly more tacit than explicit prediction processes. A prediction from a digital model or a planning slide deck are likely important to the predictive process, but actors may have a broader implicit sense of the probable future. Anticipatory systems theory suggests that having a predictive model does not require an actor to be consciousness of it, just as a beating heart or aspirating lungs do not require consciousness to keep an organism alive.

How might we incorporate surrogate time modeling into organizational theory? The organizations literature suggests that two facets of predictions are important: first how people in organizations gather and analyze information to produce predictions and second how technologies mediate the predictive process. The first is important because gathering and analyzing information is essential to prediction (Silver, 2015). The second focus on technical mediation is key because people and organizations enhance their predictive activities with digital technologies (Beunza, 2019; Leonardi et al., 2021). Information comes from many sources: from relationships with comparable organizations, news reports, membership in industry organizations, and consultants, or from actors' lived experience with past projects.

Traditionally, managers work with analysts to analyze and organize information to produce predictions and related plans for possible crises, shortfalls, or bumper years. Contingency planning has been the means by which organizations can take stock of their operations and world around them and assess how variables internal to the organization or external from the environment may disrupt their core functions (Thompson, 2017). The nature of the prediction informs any planning process such that a pandemic contingency plan involves different preparation than for an earthquake in terms of resource allocation, alterations to the organization of work, and technology needs. Studies of types of planning like contingency planning, strategic planning (Ketokivi & Castañer, 2004), or crisis management (Smith, 1990) have centered more on the preparation work than the prediction itself. By design, contingency planning can give equal weights to many predicted scenarios because the more scenarios considered, the better prepared the organization (Perrow, 1967). In moving from planning to anticipation, organizations will come to accept one prediction as most probable, such that it begins to inform action in advance to the predicted future state. It is important to understand how it happens that one prediction becomes understood as probable by people in a group or a particular occupation within an organization. We have learned from studies of technologically induced organizational change that we should look to social structures and interactions for the effects of power (Barley, 1988; Faraj et al., 2018; Zuboff, 2018), information and advice networks (Barley 1990; Rice & Aydin, 1991), and narrative framing (Leonardi 2012) on how actors in organizations understand a change process and their role in it. Beyond the expected social elements are the technologies and technical systems with and through which actors organize work within the organization.

Planning processes and modeling technologies are useful for making predictions, but predicting can also be informal. Conversations people have at work, interpretations a group makes about a presentation from management, or a report from a colleague’s conference can become pieces of tacit presumptions about the future that individuals or groups share in their day-to-day. Our understanding of casual prospections and practices of future-oriented thinking has remained somewhat limited (Augustine et al., 2019; Szpunar et al., 2014). To understand informal predictive processes, studies of sensemaking, “the process through which individuals work to understand novel, unexpected, or confusing events” (Maitlis & Christianson, 2014, p. 58), have directed our focus towards many processes. Like anticipation, sensemaking is both retrospective and prospective (Weick, 1995).The research has identified three important “sensemaking moves” that explain how sensemaking takes place through the means of noticing and perceiving cues, making interpretations, and taking action (Daft & Weick, 1984). Looking to the future as a guide for action is a basic element of sensemaking. Anticipation, however, is expressed through action, which involves not only the sense people have of the future, but also more of the action it shapes. Thus, after considering the nature of predictive information gathering and interpretation, a study of anticipation should look next to the basis of anticipatory action.

Feedforward Control. Anticipatory systems theorists describe the mechanism by which prediction shapes action as a function of *feedforward control*. Feedforward control is a form of system governance that is produced through cycles of action that are informed by an actor’s internally predictive model. Feedforward control is important because it links formal surrogate time models to the natural system. To understand feedforward loops, it is helpful to distinguish them from the concept of *feedback control*, which is compositional of cybernetic and similar systems:

> …[t]he essence of feedback control is that it is error-actuated; in other words, the stimulus to corrective action is the discrepancy between the system’s actual present state and the state the system should be in. Stated otherwise, a feedback control system must already be departing from its nominal behavior before control begins to be exercised. In a feedforward system, on the other hand, system behavior is preset, according to some model relating present inputs to their predicted outcomes. The essence of a feedforward system, then, is that the present change of state is determined by an anticipated future state, derived in accordance with some internal model of the world. (Louie, 2010, pp. 20–21)

An important distinction between feedforward and feedback is that in feedforward systems the control mechanism occurs earlier such that action in the present state has *already* been shaped by a prediction produced by an internal surrogate time model. Feedforward loops are less linear than feedback loops, in that the feedforward loops connect systems at different time scales (the faster than real time of the surrogate time model and that of the natural system) through action. In cybernetic systems, feedback is a temporally linear process through which negative information causes a reaction and adjustment, like a ship's captain reacting to information that the vessel is off course by correcting its trajectory. Whereas cybernetic systems theory positions the present as informing future action through continual feedback, this is reversed in anticipatory systems, in which a *prediction of a probable future informs and controls the present through feedforward loops*. Reconsidered as an anticipatory system, we can think of a captain's actions as always and already informed by a prediction, such that information that the ship is off course indicates an error of prediction that requires an adjustment to the formal model of the ship at sea. Anticipatory systems theory posits that we cannot fully understand the captain's actions without also understanding the prediction and resulting feedforward loops that produced the current predicament.

At first the distinction between feedforward and feedback may seem minor, but its significance emerges in answer to the question of *why* someone acts. Why is the ship off course? If we assume the ship and its crew are a part of a cybernetic, or reactive system, then the explanation relies on an analysis of negative feedback loops. Perhaps there was a breakdown in the navigation system that did not properly respond to early indicators of an incorrect trajectory. The weather may have shifted and the crew did not respond to the uptick in windspeed by adjusting the sails or engine power. These and other explanations available for any action or inaction on the part of a crew in a reactive system point towards the system of control and its basis in negative feedback loops. An analysis based on an anticipatory systems approach produces a different explanation for why the ship lost its way. The first question concerns the nature of the predictive model. What predictions of the near and distant future did the captain and the crew accept as probable? On what information inputs are those models based? Knowing this, one can assess what feedforward loops were entailed by the predictive model. The captain predicted calm seas, and thus charted a course on the basis of mild wind patterns. His weather predictions were incorrect, which explains the misdirection of the ship through stormy waters. If the anticipatory system in which the captain acts is functioning well, the experience will cause him to improve his predictive modeling and take new or different information into account when assessing the most probable weather for his journey. Anticipatory systems learn, whereas reactive systems can only improve reaction mechanisms. Thus, feedforward loops are a feature of an anticipatory system, while feedback loops are elements of reactive systems.

For scholars of technology, work, and organizations, the question becomes how organizations come to accept a *particular* future as the most probable such that it begins to shape action in the present in a feedforward process. Furthermore, just as there are conflicting goals within an organization that must be met by the work of different departments (Thompson, 2017) there may be *multiple* probable futures at work within the organization. Different understandings of probable futures may guide divergent action. Feedforward loops help explain action that is explained or justified in the context of a future not yet arrived.

One form of anticipatory action in the organizations' literature is action associated with performativity. Perhaps the most detailed example of performativity in practice comes from MacKenzie's (2006) study of futures trading at the Chicago Board Options Exchange. MacKenzie followed the creation and diffusion of the Black-Scholes model of options pricing, an algorithmic model that identified inefficiencies in the market that could be exploited through arbitrage trading. His data showed that although predictions of the Black-Scholes model were inaccurate when it was first debuted 1973, its subsequent adoption by traders changed their behaviors in ways that, over time, brought options pricing into alignment with the model's predictions. As MacKenzie summarized, the model's usefulness in helping traders to predict arbitrage opportunities "does seem to have helped to create patterns of prices consistent with the model" (p. 256). When something is performative it affects the very phenomenon that it measures, describes, or predicts. Consequently, the performativity thesis suggests a cycle constituting a feedback loop that aligns the physical world and the model that predicts it (Abrahamson et al., 2016; Barnes, 1983; Beunza & Ferraro, 2019; Garud & Gehman, 2019; Marti & Gond, 2019). Scholars of performativity talk about feedback loops in reference to the feedback from model to activity in the present. For performativity to occur, people must take a prediction for granted and then *react* to the model. Anticipatory feedforward loops are different in that they direct action with the intention of *shaping future states*. The difference between performative feedback and anticipatory feedforward is that in the latter's case, actors participate in the future by trying to bring out an optimal future state of a system, while in the former actors try to either benefit from or avoid the consequences of a predicted future event.

Anticipation may shape a wide range of technological changes represented in the literature, but there are reasons to believe that some technological change processes may entail greater anticipatory effects than others. Three qualities of technological change emerge from the application of anticipatory systems theory to organizations as potentially conducive of anticipatory organizing. First, a technological change that has a long lead time before implementation will provide more opportunity for anticipatory action (Cotteleer & Bendoly, 2006; Gardner & Rogers, 1999). In contrast to a sudden technological shock (Schilling, 2015), people within the organization will have had opportunities to catch wind of a future change and form predictions of how it may affect them, their work, and their organization. Second, a technological change that is not unique to a specific industry, similar to general purpose technologies, is more likely to make waves and gain attention across multiple industries (Helpman & Trajtenberg, 1996; Jovanovic & Rousseau, 2005). Finally, change that entails a system rather than a single tool will have greater interactive system effects, as theorized by Hughes (2012). A technological change that involves many components will be expected to impact more than one workgroup or department, and thus will likely trigger a system-level anticipatory response. Trist and Bamforth's (1951) study of technological change in coal mining provided such enduring theoretical usefulness in part because of their treatment of the new technologies as a system. For example, the transition from "hand-got" to mechanized work in the coal mines involved the adoption of many technologies at once, including coal-cutters, mechanical conveyors, power loaders, and strippers, each with variable impacts on the social structure of the mine. Revisiting a system-level approach may provide new insights into the way in which technologically induced change occurs today. The case of digital transformation meets each of these qualities.

Digital Transformation as an Ideal Case

In recent years digital transformation has been a phenomenon that both enthuses and challenges practitioners. A review of the literature on digital transformation produces a tally weighted in favor of strategy, economy, and practitioner journals. Practitioners have reported digital transformation to be much more complicated and far reaching than their experiences with the related processes of *digitization* and *digitalization* (Fitzgerald, 2013; Smith, 2021). Strategy scholars describe a phenomenon that is more driven by technologies than the people who select and use them (Hess et al., 2016). Recent literature on digital transformation has only begun to take stock of what we have learned from studying digitization and digitalization about technologically induced organizational change.

There are at least three reasons for organizational scholars to study digital transformation as distinct from digitization and digitalization with an eye towards anticipation. First, digital transformation flips the script on technologically induced organizational change processes. In the past, organizations have sought out new technologies to support their pre-existing goals and business models. Traditionally, manufacturing firms have adopted automation technologies to increase output (Silver, 2003; Thomas, 1994). With digitization and digitalization, for example, architectural firms acquired technologies like simulation software to gain efficiencies in ongoing design work (Boland et al., 2007; Groleau et al., 2012), and health organizations have sought out digital technologies to reduce error in their existing core functions (Barrett et al., 2012; Sergeeva et al., 2020). With digital transformation, however, organizations are seeking new business models to match the technologies they have adopted (Dremel et al., 2017; Fitzgerald, 2013; Loebbecke & Picot, 2015; Matt et al., 2015). Instead of boosting output, manufacturing firms are pivoting to emphasize their service offerings, becoming more platform-like in their work as keepers of the “industrial internet” (Agarwal &

Brem, 2015; Loebbecke & Picot, 2015; Malik et al., 2021). Rethinking business models during digital transformation is a source of great conflict. When an IT executive from the global shipping company Maersk announced in an interview about its digital transformation that the firm "used to be an industrial company that had technology on [the] side, but now it's a technology company where we have some physical devices we need to move around," there was rare public revolt from senior members of the organization. A veteran sea captain from the maritime business, which contributes 78% of the firm's revenue and employs 12,000 seafarers, commented that "I am very sorry, but I will have to correct you, but we are NOT a tech company who 'happens' to operate ships." The enthusiastic response to his comments indicated that the course of Maersk's digital transformation was still uncharted (Hollinger, 2021). The prospect of a business model overhaul like Maersk's is conducive both to a systems-level analysis as well as productive for anticipatory action. Like the IT executive and ship captain, actors who anticipate dramatic changes in their organizations are likely to take action to either avoid negative impacts or enhance potential positive outcomes of change.

A second reason to pursue the case of digital transformation is that it entails "digital ubiquity," or the expansion into data-intensive, analytics-based services to existing business practices and products that are applicable to a wide range of organizations and industries (Iansiti & Lakhani, 2014; Susskind & Susskind, 2017). The increase in data inputs is an order of magnitude greater than previous digital change processes such that people in organizations will perceive the potential for new data in ways that shape their impressions of probable futures. Data inputs are made possible by sensors, and sensors come in many forms. An automatic Roomba vacuum cleaner, for example, is an information-gathering artifact that suggests new furniture layouts for your room, which in turn produces novel, and sometimes troubling, insights about customers and their practices for firms (Zuboff, 2018). Digital transformation's propensity for sensors revives a quote often incorrectly attributed to Peter Drucker that "If you can't measure it, you can't manage it" (Zak, 2013). Whatever the true origin of the adage, organizations undergoing digital transformation face a deluge of data in need of management. An example from professional basketball is revealing. Coaching, refereeing, and playing professional basketball now incorporate the use of subsecond interval data from sensors worn by players, embedded in the basketball, and placed throughout arenas.[3] Each of these sensors interacts in such a way that they produce new ways of "seeing" the game. The effects of datapoints that never existed before have altered the behaviors of players, coaches, announcers, and fans and catalyzed a paradigm shift in gambling as the industry learns to adjust to sports betting's new "moneyball" era of data analytics (Gorski, 2021). Research on digital change tells us that digital ubiquity will have organizational implications beyond the strategy literature's more limited emphasis on market opportunities, efficiencies, and profit (Chanias et al., 2019; Fitzgerald, 2013; Matt et al., 2015).

Finally, digital transformation is a process that involves the adoption of many technologies at once. In contrast, much of our existing understanding of technologically induced organizational change has been advanced through studies of the development of a particular technology on the one hand, or the effects of that single technology on the other. In the case of the former, studies of technological development have centered on artifacts like the bicycle (Pinch & Bijker, 1984) or the bubble chamber (Pickering, 1993) to explain a

[3] https://www.nytimes.com/2021/05/28/sports/high-school-basketball-shot-tracking-technology.html

technology's development. Regarding the effects of a technology, scholars analyze both the process and consequences of introducing a particular technology into one or many organizations (Bechky, 2019; Christin, 2020; Orlikowski & Scott, 2014). Research designs of this persuasion generally track one technology longitudinally through implementation and use, as in the now canonical cases of the introduction of CT scanners into radiology departments (Barley, 1986) and of computers into insurance firms (Zuboff, 1988). A framing around a single technology has been productive for isolating and theorizing the effects of a technology on the system around it.

Digital transformation is not a process of adopting a single technology. This means that the research framework on which we have built theory about technology and organizational change falls short. The innovations that have accompanied digital transformation in the form of agentic technologies like artificial intelligence and machine learning have meant that not only are there many more technologies being adopted in one project, but that the reach of those technologies are being much more broadly integrated with existing technical infrastructures (Agarwal et al., 2010). Old technologies are being equipped with advanced sensors that combine to produce novel data streams about micro-level activities. Studying digital transformation's norm of implementing many different technologies at the same time or in quick succession necessitates a systems-level approach. An analysis of prediction and action can help to frame questions about the adoption of complex systems. Do technologies only affect structure at the moment of impact or before? Does the manner in which the first tool becomes implemented affect expectations and implementation of the second? Is there an anticipated sequence that affects action on site?

Research Questions. In this dissertation I asked how the anticipation of technological change shaped structure and action within the receiving organization before technologies arrive on site. If organizations are social systems made up of many kinds of people in different occupations and doing different tasks, people in different positions will have access to different kinds of information. We must first understand the ways in which individuals and groups make predictions of probable futures about their organizations in the context of technological change. After we understand the ways in which actors in organizations make predictive interpretations, we need to subsequently understand how these predictions guide action and influence structure. I consider the phenomenon of anticipation in the context of two separate organizations going through a similar process of digital transformation. The following questions emerge from my analysis:

RQ1: How do organizations anticipate digital technologies?

This question guides an investigation into how actors in organizations gather and interpret data to make predictions about technological change. Information about the future can come in many different forms of input, including from professional associations, coworkers, or reports produced by consultants, managers, colleagues at similar organizations, etc. Actors interpret data and make predictions about their job, their organization, and the type of work they will do when the new technologies are implemented. The form of the prediction, i.e., formal and written down or informal and discussed in an ad hoc manner, will likely vary across department, occupation, and organization. Part of answering this question will include analyzing how predictions shape action in anticipation of technological change.

Example: Technicians at one organization may have had experience with a transition from analog to digital technologies. They may have been anxious about being laid off *in the past, but they have experienced how labor intensive it is to maintain the finicky new digital technology. They predict that digital transformation could improve their job by increasing its status in the organization as more technologically advanced. Technicians at a different organization, however, may have seen colleagues in other industries get laid off after digital and automaton technologies were adopted. They may experience a higher level of anxiety and begin looking for jobs in other industries to get ahead of digital transformation. Managers at both organizations, on the other hand, may talk often with consultants and as a result will have learned what a powerful tool the new data will be for their organization. Rather than working with the technicians to understand their experiences with past technologies or assuage their anxieties, they spend most of their time trying to bring along other departments in hope of expanding the impact of digital transformation during implementation and use.*

RQ2: How does anticipation shape organizing?

This question builds on the previous in assessing how the actions people take on the basis of a probable future trigger change in advance of technology selection. How does anticipatory organizing shape the organization of work? People may organize into both informal and formal groups to study and bring digital technologies to their organizations. Senior managers may hire more technically skilled people to prepare for the technology. Tenured employees may see the coming technology as complicated and use it as a reason to move forward with retirement. Change in organizing may shape the activity and performance of workgroups. Work output may be affected in positive ways if actors are trying to work hard and position themselves as important to the new technology, or other technologies may go without maintenance if decision makers anticipate their imminent replacement.

Example: A technology workgroup anticipated that some key decision makers might not understand why such a major investment was needed for the organization IT infrastructure. To bring them into the fold early on, a supervisor decided to include them in the early pilots so that decision makers could use and get to know the technology. Meanwhile, a long-time field technician expressed a desire to avoid having to learn how to use the new technology and opted to retire in the middle of the planning process. Losing his knowledge was a loss for the staff who stayed on, who were unable to answer questions about problematic components, the organization of work, and the creative ways that the retired field technician solved problems with the data integration process.

RQ3: What are the implications of anticipation for materiality?

Because this dissertation is a study of technological anticipation in the years before organizations adopt a new technology, it is possible that anticipation will shape the materiality of the system that the organizations select. Expansive predictions of digital transformation may weight the selection process towards systems that will better integrate with other departments' software. More narrow predictions of the application of digital change may incline people to select a technology that works best for one area of work over another.

Example: In their research into how others have used a particular technology, people at one organization learned about a comparable organization that used the technology to improve both modeling and planning. They had many conversations *with the modelers and anticipated using data that the new technology would produce. Engineers hoped others in the organization would use the data and improve interdepartmental planning work. To this end, they sought out a technology that would integrate easily with software systems and simulation technologies used by multiple departments. One of the firms bidding on the project included in a scope of work to write a series of unique algorithms to seamlessly integrate their proprietary software to the organization's existing software. Thus, the anticipated application of the technology shaped the production of new integration algorithms during the selection process.*

Organization of This Dissertation

To answer my research questions I explore how people at two water agencies anticipated the arrival of a new digital technology called Advanced Metering Infrastructure (AMI). Chapter 2 explains the setting of this study, its methodological foundations, and my analytic approach. I discuss the reasons for choosing an ethnographic method and why both AMI and the agencies I selected are a compelling design for the study of the anticipation of digital transformation. I detail how I collected and analyzed my data to produce this dissertation.

I begin the story of Suntown and Fogtown's anticipation of AMI in Chapter 3, describing how ad hoc groups formed at both agencies to learn about and get ready for AMI. I explain how at both agencies people developed shared predictive frames about the new technology through sequences of information seeking and organizational action. I document through analysis of my interviews and observations of the early activities how people continually applied new information and experiences to their predictive frames. I suggest that

Suntown's more extensive activity sequences shaped more expansive frames of AMI, while Fogtown's cessation of activity due to resistance within and outside the organization contributed to more narrow framing of AMI's future at the agency.

Chapter 4 details the intensified involvement of senior managers in the AMI project work after they approved the project to move forward. This chapter focuses on the phenomenon of anticipatory control, and looks at how senior managers took cues from their staff's earlier work to make executive decisions to prepare the organization for the eventual adoption of the technology. I detail how the degree to which AMI aligned with senior managers' strategic planning projects contributed to their decisions. The chapter's focus is on Suntown's decision to initiate a major departmental reorganization and Fogtown's move to cut repair budgets of the existing meter system and their consequences. This chapter shows how extensive anticipatory organizing was for both agencies, as anticipatory control affected many people's work and was justified by the future implementation of AMI.

In Chapter 5 I explore how anticipatory organizing at both agencies shaped the process of selection and the related material configuration of the systems each agency purchased through their procurement processes. From my observations, interviews, and related documents I show how Suntown's group of selectors took cues from their predictive frames and the organizational changes they were beginning to undergo in the departmental reorganization to seek out a highly customized AMI system to meet their developing needs and goals. Fogtown, in contrast, took a more limited approach to selection that curtailed opportunities for customization.

Finally, in Chapter 6, I explore the implications of understanding organizations as anticipatory systems. The argument I advance in this chapter is that technologically induced organizational change begins not only sooner than we have previously assumed, but that the change process does not rely entirely on the experience of users as they interact with the technologies in question once they are on site. I propose a model of organizations as anticipatory systems that can frame future research. I then theorize what my findings mean for the study of work, technology, and organizing. I argue first that the process of predictive technological framing is an important facet in the process models and theories we have now and will continue to develop, in that the way in which people first perceive new technologies can condition structure and action in the present. I subsequently posit that, as a study of the antecedents to implementation, my findings have additional implications for explaining later processes in organizations as they adopt and begin to use new technologies. Anticipation is an important part of what comes later in organizations as they undergo the adoption and implementation of new technologies.

II. Studying Technological Anticipation

Finding a way to study something that has not yet "happened" is a tricky way to begin designing a course of research. In the last chapter I laid out several reasons why I think we have not yet investigated the phenomenon of technological anticipation, and I believe the methodological limitations are no less of an explanation for the gap in our knowledge than our theoretical assumptions. How do people in the organization, much less a researcher, know that the adoption of a new technology is on the horizon? I posit that there are two ways to find an appropriate setting for the study of anticipation, which are either by accident, or by finding organizations that have not adopted a technology that others within their institution have. Perhaps because the accidental discovery of a phenomenon takes at minimum a great deal of time, we see examples of it in the introductions to anthropological and ethnographic studies. In his study of a small, remote reindeer herding community in Northeast Finland, Pelto (1973) had already returned home from his year of observation when he received a letter from one of his informants. The letter described how a few members of the community were acquiring gas powered snowmobiles, and suggested Pelto might be interested in coming back and seeing what was happening in the community in light of the arrival of the machines. Pelto was able to secure funding and returned, and thus could use his prior research to put together a story that encompassed a rich description of life *before* the snowmobiles. He did not produce an account of anticipation, but through change he was able to tell a much richer story of life before the events of technological change that have made his account still shared among anthropologists and ethnographers.

The second approach could be through a careful tracking of technological change in an institution. If organizations within a particular industry are making a shift to a new technology such that it has become regarded as "where things are going," then it seems likely that there will be sets of organizations that have not yet but intend to make a similar change. We can feel confident in technological trends because of the tendency towards organizational isomorphism and a tendency towards homophily (DiMaggio & Powell, 1983). But, as DiMaggio and Powell explained in their research on this topic, this will bear out for technological change that has shown to be *successful*. My study is an example of this latter approach. Like any study, however, there was also some degree of luck. I had intended to study a technological change in an organization before, during, and after, but realized after a year that what was actually happening in front of me was an extended period of anticipation. What first drew me to my research sites was that there was a digital shift happening in the institution of water management.

Digital Transformation in Water Management: Advanced Metering Infrastructure

Water management is an ideal context in which to study anticipatory organizing and digital transformation. When I started this study, cities everywhere in the United States were undergoing a major technological shift in how they managed water infrastructure (Lape, 2013). Water utilities were adopting automated digital technologies that promised to both radically change the work of water departmental staff and introduce novel and exponentially greater amounts of data and automated decision-making about water infrastructure and usage. Thus, the field of water infrastructure was undergoing a change that would likely reach every city and small town in the US. Information about digital transformation had circulated among agency workers at regional and national industry conferences. There had been a long period for people to begin to anticipate technological change at their own organizations. Furthermore, water agencies are autonomous entities that make their own decisions and upgrade on idiosyncratic schedules, as long as they adhere to state and federal regulations. This suggested there would be variation across agencies in their approach to digital change. While water agencies share similar goals of delivering clean, safe, and reliable water service to their customers, their approach to reaching this goal differs by city and region. For example, water agencies in wealthier cities have more resources to devote to piloting new technologies and improving infrastructure, while cities in worse financial straits can compromise their system by using older or less safe infrastructure technologies (Lyon et al., 2017; Montgomery & Dacin, 2020). At the time I began my study, digital transformation in water infrastructure had begun but had not yet reached the majority of water utilities. It was thus the ideal time to study the anticipation in an environment when early adopters would have shared their experiences with others. Finally, as old organizations (many are as old as their cities' founding), they would have differing "initial conditions" of technologies, practices, and structures that would be likely affected by predictions of change. The similarities and differences across agencies supported a study that considers multiple variables of change.

The primary digital transformation underway in US water agencies was called Advanced Metering Infrastructure (AMI), which replaced older systems of traditional metering and water billing. The purpose of traditional metering systems has always been to measure, account for, report, and bill for water use over a billing cycle. Traditional systems used mechanical meters and meter registers that human meter readers visually check on a monthly or bimonthly schedule. Meter readers digitized analog data from the meters by inputting reads into a handheld device. The data from meters was then manually verified in the meter shop and billed by a utility's billing department. With AMI, utilities were upgrading their metering infrastructure to automate almost every step in the metering process. As managers upgraded their systems, utilities had the option to build a great number of new, intelligent affordances into the system. As one informant explained,

> We didn’t invest in this system just to replace metering. We’re expanding into every corner of our organization to not only automate old processes, but use the data to see our system in a whole new way. We’re just beginning to see how much we can do with the kind of data granularity we’re getting out of AMI.

AMI systems can capture both a higher quantity and variety of data at the meter, transmit it back to the utility over one of many different types of networks, and analyze and report on the captured data in different ways. AMI systems automate many tasks that were previously done by utility staff, including water usage data collection, reporting, and alerting customers of leaks. AMI systems rely on up to three different kinds of software to store, verify, analyze, report, and display data for different users. Because there are many kinds of technologies on offer for each component of an AMI system, a utility beginning the process of technological change will find that they can customize their AMI system with great latitude. One utility may want to build an AMI system that can not only automatically capture hourly volumetric reads, but also measure temperature or pressure. Because information collected by an AMI system must be transmitted over a network to central data collectors, a site’s topography will determine what kinds of networks can reliably transmit data from every water customer. The type and quantity of data one AMI system can produce and process varies greatly from one utility to the next. For water utilities the transition from traditional meter reading to AMI requires a reconfiguration of the many interconnected components of a traditional meter reading system. Figure 2.1 depicts some of the differences between the meter-to-cash process in traditional and advanced metering infrastructure:

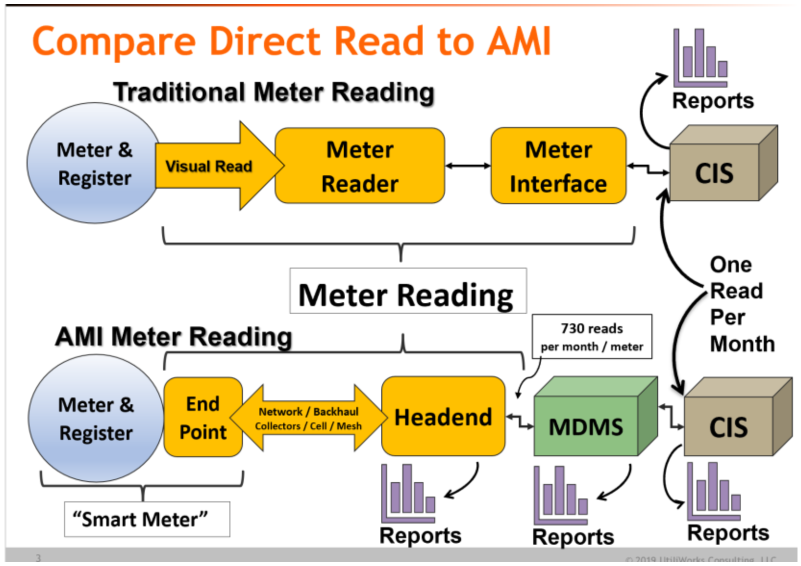

Figure 2.1. Traditional & Advanced Meter Reading. Headend and MDMS (Meter Data Management System) are software that validate and aggregate data from the meter. CIS is the utility billing software, or "Customer Information System."

The top half of this figure depicts "traditional meter reading." The components that make up a traditional system include a meter through which water flows from the agency's pipes to the customer's house. As water flows through the meter, a disc inside the meter nutates (or wobbles) in response to pressure. The precise cycles of the nutating disc mechanically trigger a resister which records the flow. During a "read," meter readers visually read the register and enter the account's usage into a large, handheld device that they carry with them. Meter readers read meters on "routes." Service areas are divided into 4–10-mile routes that meter readers either walk or drive once per billing cycle. After completing a route, meter readers return to the office and transfer the data to a central computer with a meter interface software. An office worker than compiles and verifies the data before sending it to the billing office. At the billing office, billing staff use a "customer interface system," or "CIS" to convert the volumetric data to bills that are sent out to customers. The CIS program is more advanced than the meter interface, and can produce reporting on customer behavior (unpaid accounts, unusually high bills, unusually low bills, etc.).

Before AMI systems were available, some utilities upgraded to an Automated Meter Reading (AMR) system. AMR systems enhanced traditional systems through a small radio transponder (widely referred to in the industry as an “endpoint” or “MXU”) that was affixed to a meter body. The endpoint converts the analog signal from the mechanical meter, or reads a digital signal on a digital meter, and broadcasts it on demand to a nearby collector unit. This meant that meter readers could either walk the route without stopping to check each individual meter, or collect reads from their vehicle. Some cities installed 100% AMR meters, while others prioritized dangerous or hard-to-reach meters for a switch to AMR. Importantly, AMR systems still produced one volumetric read per month.

AMI systems are different from traditional and AMR systems in two ways. They involve many additional technical components, and they produce a great deal more data. The bottom half of Figure 2.1 shows an AMI system. Like AMR systems, AMI systems have an endpoint affixed to the meter. What is different is that AMI transponders collect data at much more frequent intervals, ranging from every hour to every three minutes. They can also collect and transmit more kinds of data, such as water pressure and temperature, or send alarms about tampering. Data are transmitted over either cellular or radio networks (often called the “backhaul”). Agencies that use cellular networks can use preexisting 4G and 5G cellular networks, while agencies that use radio networks must license a frequency from the Federal Communications Commission and build their own network infrastructure. Radio network infrastructure uses data collector units. AMI systems use more software. Data collector units use software called a “headend system,” which IT staff can use to track how the raw data are being captured and stored and check network health. A Meter Data Management System (MDMS) enables agency staff to access and work with data produced by the system. The MDMS sends data to the billing office, where staff will produce bills as with a traditional system. A comparison between traditional and advanced systems reveals the many choices utilities have to make about each component, the infrastructure that supports it, and the data outputs it can produce.

Utilities anticipating and planning for AMI had many different technologies to consider. AMIs integrate sensors, data aggregators, and dashboards to provide micro-level data that promises to help detect leaks and to educate customers about consumption patterns. Many water agencies around the country were implementing a suite of new technologies to produce new sources of data and more granular sources of data on customer use, system leakage, tampering, backflow, pressure, and temperature. These digital technologies work together in real time to provide operational data that has the capacity to enable newly proactive, preventative, intelligent, and more efficient water management and delivery. The avalanche of data produced by these digital technologies may be useful for more effective water management programs, but the data need to be acted upon, organized, and integrated into the broad operations of a water agency. Cities often expect that data-enabled increased visibility into water flow would not only help them respond quickly to fix leaks and broken delivery systems after natural disasters, but would also assist them in identifying which infrastructural components are at the greatest need for preventative maintenance. Many managers have learned from comparable agencies and consultants that they need to transform their organizational structure and business practices to take advantage of the affordances of AMI, and many begin these changes long before firms are contracted to implement AMI technologies. By changing the metering devices, cities will have, for the first time, real-time and micro-level data on water usage and distribution. In short, this advanced metering will create a digital transformation by providing massive quantities of data useful for thinking about how the city should maintain, repair, and design the entire water infrastructure, and how that infrastructure links to other municipal water sources.

Site Selection and Data Collection

This dissertation is based on a three-year study of two Californian water agencies in advance of undergoing a shift to AMI. I call them Fogtown and Suntown.[4] A California-based multi-site study introduces several advantages for research. While the state deviates from the US norm in areas of regulation, planning, and integrated infrastructure systems, many policies and regulations in fuel and energy efficiency initiated in California have influenced national standards. Because Californians makeup 10% of US auto buyers, for example, the state's fuel efficiency regulations have influenced auto production standards and norms (Frazin, 2020; Schmidt, 2007). A factor specific to this study, for example, is an impending state requirement that water agencies show an annual reduction in internal water loss. Californian water loss legislation is modeled after policies first introduced in Southern states like Georgia and South Carolina, and now half of US states have implemented some measure of internal water loss regulation (Jernigan, 2014). Agencies report preparing for this by pursuing technologies that enable more precise tracking of water assets. The ways in which California water agencies are managing digital transformation in water management will provide a comparative framework for growing our understanding of technologically induced organizational change.

[4] All names of places, landmarks, people, and companies have been changed to preserve their anonymity.

This study builds theory using comparable agencies that provide case-based empirical evidence as a basis for new theoretical propositions (Eisenhardt, 1989). I included questions related to my initial theoretical propositions to test out initial ideas for the theory development at multiple levels of analysis (Yin, 1994). Case studies are multifaceted investigative approaches to the study of social and organizational life (Feagin et al., 1991). I designed this research using a case study approach for two reasons: first because of the diversity of data sources the approach requires (i.e., interviews, document analysis, surveys, etc.), and second for the depth of study it affords. Case study research is a proven approach for building theory on technological change (Eisenhardt, 1989) that has only steadily increased in relevance since 1980 (Green, 2016).

Scholars of technological change have relied on multi-sited studies to develop "new forms of intervention, focusing often on dialogue and the emergence of negotiated solutions rather than a straightforward linear move from research to recommendations" (Hine, 2007, p. 653). Data from sites engaged with the similar technologies in the face of drought supports the development of a "middle range" theory of the sociotechnological change (Merton, 1968). A two-sited comparative approach provides a basis for the researcher to give context to the significance of a study's findings through comparison and contrast (Marcus, 1998). If, for example, one organization had success hiring a data analyst in the meter reading department, but another tried and failed in this strategy, the contrast reveals the risks and rewards of that particular strategy. I have gathered an extensive amount of ethnographic data over the three years of my study. In total, across my two sites, I conducted over 100 interviews, observed work for more than 700 hours, and collected thousands of photos and documents. Additionally, I conducted 22 interviews with comparable water agencies who had already implemented similar digital technologies with questions focused on their experiences after implementation. This interview dataset includes agencies in other parts of California as well as other states and one private water agency.

My data collection unfolded over three phases. In the first 18 months I focused exclusively on a single site in a longitudinal study of its early consideration of AMI. My goals during this time were to understand the work required to produce and capture volumetric data at the meter, collect and process that data, and distribute bills to customers. Through ongoing memo writing and consultation with the literature, a theme of anticipation emerged. Curious if the initial evidence of anticipatory organizing at my one site was unique, I initiated the second phase of research to include additional sites for comparison. I began observations at two further sites going through similar transitions to AMI technologies. One of the two sites (Fogtown) shared many similarities to my initial case study at Suntown (timeline for implementation, population size, topography, demographics, water rates, etc.) but was different in a few ways that made for an interesting theoretical comparison.

The first difference was in agencies' baseline meter technologies. In the 1990s Fogtown had transitioned from manual meter reading to a metering system called Automatic Meter Reading (AMR).[5] This meant that instead of transitioning from a fully manual system to an automated digital one with AMI, Fogtown was shifting from an already digitized, "drive by" AMR system to AMI, the latter of which is managed remotely without visiting the meter on foot or by car. The transition to AMR meant that Fogtown workers had gone through a digitization process that transitioned the meter reading process from analog to digital (Leonardi & Treem, 2020). Over a decade, Fogtown experimented with several digital

[5] See Appendix 2 for a history of Fogtown's transition to AMR.

metering technologies and had developed both opinions about and expertise in maintaining the system. The literature on prospective sensemaking and agency suggests that this experience could shape Fogtown's impressions of the future, such that its workers might anticipate digital transformation with AMI differently than their counterparts at Suntown who faced a more significant transformation from analog to AMI (Emirbayer & Mische, 1998; Gioia et al., 2002).

The second difference was in the relative political involvement of the city's citizens. Suntown was home to many nonprofits and activist organizations, but their membership was more inclined towards community service work than political agitation. Suntown's water agency was more experienced with NIMBY protests about construction happening in residents' neighborhoods than long-term, effective opposition to water projects. Suntown successfully pushed through several major water supply projects in the decades preceding this study. Fogtown, in contrast, has a history of grassroots militant activism that had derailed several major water supply projects in recent memory. Anti-5G protestors were active at both cities, but management at Fogtown was much warier of their impacts than their counterparts at Suntown. An organized and active anti-5G group was important because they actively opposed the installation of both radio and cellular transmitters on any kind of residential utility meter. The justified their resistance with widely debunked[6] claims that that so called "smart meters" caused cancer and were bad for people's health. Studies of technologically induced organizational change have shown that differences in political activism can have significant effects on the change process. For example Robey and Sahay (1996) found that

[6] For more information, see the American Cancer Society's report on smart meters: https://www.cancer.org/healthy/cancer-causes/radiation-exposure/smart-meters.html

influential groups with strong opinions affected whether the adoption of GIS at a county government was deemed to be a radical change of great interest to many parties versus one that was barely noticed (Boudreau & Robey, 2005).

Finally, the agencies' dependencies on their local watersheds made for a significant difference in the degree to which their water supplies were vulnerable to drought. Fogtown relied 100% on annual precipitation to harvest water from its single reservoir, river, and groundwater wells. Even a single year without rain was cause for alarm and discussions of drought restrictions. Suntown, on the other hand, had built several supplemental access pipelines that allowed the agency access to additional supplies when local rainfall was insufficient. The differences in the two agencies' resource dependencies has implications for power relations, behavior, effectiveness, and many other factors both internal to the organization and between it and affiliate organizations (Hillman et al., 2009; Pfeffer & Salancik, 1978; Schnittfeld & Busch, 2016). It is also clear that water shortages are an existential source of conflict between organizations, regions, and countries (Espeland, 1998; Wolf et al., 2005). It is therefore reasonable to expect some degree of political tension to follow from perennial shortages in supply, and given that AMI technologies can be used to improve conservation efforts, these tensions should affect the way in which the technologies are anticipated in the context of heightened scarcity. In the third and final phase of data collection, I focused almost entirely on the second site to build out a set of interview and observation data comparable to the first. Key similarities and differences are in Table 2.1:

Table 2.1

Comparable Variables Between Fogtown and Suntown's Water Agencies

	Fogtown	Suntown
Population served by water system	90,000	90,000
Household area median income	$75,000	$75,000
Type of agency	Division within municipality	Division within municipality
Topography	Coastal	Coastal
Monthly cost for 4 HCF of water in a single-family home	$50	$50
Complexity of water system	Moderate	High
Dependence on annual rainfall in immediate watershed	High	Moderate
Citizen involvement in local politics	High	Moderate
Dominant metering technology	AMR	Manual

The many similarities between the two cities, including service area, topography, median income, and water rates provide for a strong basis of comparison. Their shared position as a division within a municipal organization meant that they would have similar organizational processes for making changes to job titles or organizational structure. Both would have to gain approval from their city's human resource department for any formal organizational changes. The differences between the two sites have the potential to advance our understanding of organizational change in several ways. The differences in the complexity of the water system are a factor of the number and types of supply inputs (i.e., groundwater, surface water stored in reservoirs, access to supplemental state water, recycled water, and water from desalination plants). Research has shown that differences in complexity can influence the nature of technological change in organizations (Desanctis & Poole, 1994).

My approach was primarily ethnographic, consisting of extensive time in the field conducting participant observation, semi-structured interviews, and short interviews in the process of observations (Van Maanen, 2011). Ethnographic observation enabled me to fully immerse myself in the interactions and organizing structures at my sites so that I could capture rich data on interactions and organizing structures which are important to the study of technologically induced organizational change (Barley, 1990; Orr, 1996). My interest in anticipation and digital transformation had led me to conduct comparative analyses between what my informants said and wrote about the future and how they acted, which I have found is best captured through a combination of observations, interviews, and document analysis. I chose a case study approach so as to focus on dynamics of digital transformation in single and comparable settings. A table with an overview of the data I collected is below.

Table 2.2

Overview of Collected Data

	Suntown	Fogtown	Comparable agencies
Observations	171 (684 hours)	45 (120 hours)	25 (27 hours)
Interviews (30–90 minutes)	40	27	26
Documents and photos	800 documents > 3,000 pages	2,100 documents >10,000 pages	<200 documents
Surveys	5	2	2
Departments	Metering, Billing, IT, Distribution, Conservation, Customers, Public Meetings	Metering, Billing, Conservation, Public Meetings	

It should not go unnoticed that the COVID-19 pandemic took place halfway into my data collection. The lockdowns that followed the outbreak made life difficult for ethnographers everywhere. For this study, however, I was surprised to find many benefits to doing stretches of research from home. For one, I had already spent a year in the field doing participant observation. As water agencies are essential services, all of my informants continued to work with modifications for safety. All of the planning meetings for AMI moved onto video platforms, and I was able to attend each of them. For the informants I was following who did not attend planning meetings (i.e., meter readers or billing staff), I increased the number of interviews I conducted with them by phone. I would call people both planned and unannounced and catch them while they were at work or taking a break, and we could continue to have frequent conversations about their work. Many of them expressed how much they enjoyed having someone check in on them regularly, and more than one informant referred to me as their “work therapist.” Once vaccines became available and society began to open up, I was able to pick up my in-person observations again. Both agencies continued having AMI meetings online, however, so no matter which city I was in, I was able to continue to capture AMI planning meetings by attending online.

For the duration of this study I captured data from a combination of sources, including notes from observations, interview transcripts, surveys, emails, photographs, screenshots, archives, news coverage, and public records. Because I am interested in the process of digital transformation, I conducted a longitudinal study that enabled greater depth than it did breadth. Technological change processes are not only time intensive, they can involve the participation and work of an increasingly long list of participants. Thus, I designed the study around two sites undergoing the same type of digital transformation at the same time. Finally, I have collected attitudinal survey data from respondents about their ideas of the coming technological change and how they anticipate its future effects on their work, which provides an exciting comparison to my interview and observational data.

Analytic Approach

My preliminary analysis, developed through open coding and memo writing, suggested three phases of anticipatory organizing for digital transformation. These phases were 1) early organizing of predictions of technological change, 2) anticipatory control by senior managers, and 3) selection through a procurement process. The phases were sequential. The early work within the agencies of organizing predictions involved the gathering of information to predict the nature of digital transformation in the organization. Later, predictions then informed the actions of senior managers who were responsible for the whole division's successful production and distribution of drinking water. In the third phase, organizations selected of the specific technological systems they intended to implement. Organizations have many options for each component of an AMI system, and much work went into selecting individual components and linking them together through formal procurement processes. I have organized my findings into three chapters that generally reflect these three phases.

I took an inductive approach in this study and built theory grounded in the data (Corbin & Strauss, 2015; Glaser & Strauss, 1967). My analysis comprised an in-depth comparative analysis of the differences and similarities between the cases (Eisenhardt, 1989; Eisenhardt & Graebner, 2007). While collecting data, I engaged in regular comparison of data and theory through memo writing to inform the focus and breadth of my data collection (Eisenhardt, 1989). I next explain my analytic approach for each of the three empirical chapters in this dissertation.

Early Anticipation and the Development of Predictive Technological Frames. To understand predictive technological frames, I conducted a round of selective coding to analyze the means by which actors developed predictions of digital transformation in their organizations. I looked for instances when people talked about the future. The processes that emerged from this coding that are most important to this analysis were those related to information gathering and framing. I wanted to be able explain which actors had access to what information channels and how they synthesized new information with past experiences to develop predictions, for example a 60-year-old meter reader who laughed and said, “They have been talking about AMI for 20 years, I’ll believe it when I see it,” or distribution supervisors who suggested, “They’re going to need to include us to make AMI work because we’re the real technology people in this organization.”

It became clear that action around AMI was happening around a group of four or five people at both agencies who organized themselves into a regularly-meeting group to research and plan for a transition to AMI. I called this group an “ad hoc” group and focused on the individuals and the group as my units of analysis. I was interested in understanding interactions between individuals so as to understand the social process and what happens when people came together as a workgroup and influenced each others’ sense of the future. The number of people involved in making predictions and their relative influence in the organization is important to understand.

The data I used in this analysis included interviews, observations, emails, documents from the agencies and from consultants, and reports written by memos of the ad hoc groups. I was curious about the early stages of anticipation, so I bookended the first chapter as beginning when people first started talking about AMI in my data and ending when managers at both agencies gave their approval for the project to progress further. I compared my ethnographic data with the results of attitudinal surveys I conducted of staff at each organization. Finally, I looked to the ways in which people communicated predictions through text, in the form of internal newsletters, reports to managers, and formal presentations to the water commission and city council.

In an additional initial round of selective coding I explored emergent themes about how people talked about AMI. When codes about AMI and the future overlapped, these made up instances of predictions about the technologies. But people talked and wrote about AMI not just as a future phenomenon. Because I was interested in how people in organizations heard and learned about AMI technologies, I coded my observation notes and interviews for instances of information input and moments of discovery. I compared how people in different roles gathered and understood information about possible futures with AMI. Sources of information that emerged from my analyses include attending industry conferences, calling colleagues in other agencies with questions, answering requests from HR, soliciting reports from consultants, and running pilot programs. I compiled a running list of all sources of information from each agency. In my constant comparisons of the codes between the two agencies, it became clear that people at Suntown undertook more efforts at information gathering from more diverse sources. This led me to abstract these instances for types of "information seeking," and engaged in continual comparison between the agencies to understand the similarities and differences between the ways in which people gathered information about AMI.

In writing memos about information gathering I began to uncover the nature of the framing process of this early phase. I realized that instances of information gathering were related to predictive statements. Thus, I compared codes from each site for any instance when a person talked about the future of metering, AMI, or the organization as it related to technology. Here I expanded my analysis to include five years of Fogtown's weekly division newsletters. After a period of conflict between management and the meter shop about funding for a meter replacement program, management gave one of the utility account specialists a monthly column in the newsletter to update the department about meter activities. Some of the newsletter pieces have come up in interviews as important moments of information sharing about metering technology's potential.

I was not on site at Fogtown for the same amount of time as at Suntown, and thus I used the weekly newsletters to understand what ways people were talking about the metering system to their colleagues. I coded instances to differentiate between an expression of a goal for the future (i.e., "with AMI I want to get the meter readers more involved with customer service"), and a prediction of the effects of technology (i.e., "the amount of data we are going to get with AMI is going to be crazy"). I then differentiated between goals and predictions according to the topics of concern, i.e., predictions about customer interaction, changes in billing, what legislation or regulations would come into play, etc.

It became clear that some predictions and goals were for the short term, while others referenced a more distant future. I then abstracted all of my prediction and goal codes to categories of "short term," "mid range," and "long term." This enabled me to see how predictive frames were changing over time at Suntown to become more encompassing of a long-term vision of change, while at Fogtown discussions remained much more rooted in the near-term future. I compared these to the results of my survey of organizational members about their attitudes towards AMI in which I posed six questions to about 100 members in each organization who would be possibly affected by AMI technologies or data about how they anticipated the technological change. I built out an understanding of the predictive technological frames by doing further axial coding at higher levels of abstraction that revealed three elements to each frame: the application of the technology (from narrow to broad), the temporal horizon (soon to distant), and the related need for organizational change (minimal to major).

I then coded for the actions that people took during the period I had marked as “early anticipation” before official approval. The types of actions that emerged from coding changed either material infrastructure or the organization of work related to the AMI program, for example making needed infrastructure placements in metering, hiring, and directing of consultants, or running pilot programs. I organized the development of predictive frames, instance of information gathering, and organizational action into two distinct trajectories for each agency that encompassed the sequences of activities that made up the work of predictive framing at both sites.

Anticipatory Control. In the fourth chapter I looked to the action of senior managers. In Chapter 3 my unit of analysis was individuals and the ad hoc workgroups that formed at each agency, but through my initial coding it became clear that senior managers became much more engaged in the AMI projects after they gave approval, which helped me partition the third chapter from the fourth. Thus, my unit of analysis in this phase was the senior managers and their actions to effect changes at the meso-level of the organization. I was interested in how predictions about digital transformation combined with other organizational needs, pressures, and goals beyond the work of the ad hoc group and focused on senior managers as my unit of analysis.

I coded for interactions between senior managers and the ad hoc groups when they talked about and made decisions related to the AMI project. I looked for effects of those decisions and coded them selectively. For example, reports to the water commission and city council were important in this phase of analysis, because both agencies are required to keep the commission and council abreast of the state of infrastructure and repair. City council and water commission meetings are part of the public record, and thus I had access to many years of recordings of council and commission meetings. Other examples that emerged from my early analysis suggested that at Suntown actors drew on environmental indicators from institutional change and past experiences to populate their predictions and take actions that influence decisions about their respective digital transformation projects, including influencing employee retirement decisions, selecting for older, more reliable technologies over untested new models, and rewriting contract terms to ensure greater organizational control of new digital technologies. In contrast, Fogtown's archival and ethnographic data revealed a process of delayed maintenance, shifting blame for lost revenue, and declining public perceptions all in the name of AMI.

Once focused in on the role of the senior managers, I conducted a round of open coding of all of my interviews and observations with them. Themes emerged from this analysis of managing the whole organization, framing projects within the context of an overall strategic plan, and a repeating practice of reminding colleagues of the goals of the organization. I then selectively coded to look for the ways in which senior managers presented AMI to their peers across the municipal organization. For Fogtown, I additionally coded the message from the director included in the weekly newsletter to the department. Even from my initial coding for emergent themes it was clear that managers talked about and took actions related to the *whole* organization more than the staff who worked for them. Managers at both sites were both responsible for strategic planning processes and talked about them often in their meetings and correspondence with staff. I then turned to archival sources about both senior planning processes and coded the documents along the categories of goals, anticipated changes within and outside the organization, and the role of technologies in their future plans. Through axial coding I abstracted these codes to instances of “integration,” “technological change,” and “organizational change,” which I compared between both agencies. Through this comparison it became clear that AMI played a much more integral role in Suntown’s strategic planning than at Fogtown. Suntown’s senior manager used the same broad, ambitious language for the agency’s future as he did for AMI. Fogtown’s senior manager rarely connected the two phenomena. Another difference that emerged when assessing the follow-up from strategic planning was that at Suntown, strategic planning continued through monthly meetings with diverse participation, while at Fogtown the planning ground to a halt and was the sole responsibility of the director.

Because strategic planning was so important for both directors, I looked for instances when AMI connected with strategic planning. While in my coding I found many examples of AMI’s integration into Suntown’s strategic plans, I did not find much of a basis of comparison at Fogtown. This led me to want to understand why AMI played such an apparently different role at the two sites. To answer this question I coded my observations of meetings between the AMI ad hoc groups and their directors, and any emails and communications with the director about AMI. From this analysis I was able to identify that the language people used as well as the way in which they positioned (or did not position) AMI to larger organizational goals was distinct. I abstracted the language into categories of scope, from narrow to broad.

It was at this point that through my coding I had compiled a series of decisions made by each director. I organized instances of decisions and compared them with both their justifications and outcomes, which led me to apply the constructs of surrogate time modeling and feedforward control. This led me to a round of theoretical coding for instances of either construct. In both my interviews with senior managers and my observations of their discussions with others, they talked about the future state of the organization. These I coded as the surrogate models of the organizations held by managers, but they more broadly encompassed the whole organization. My codes for surrogate models were different from the predictive frames I analyzed in the previous chapter. Frames were a way of looking at the technology and how it would be useful, and how broadly it would be applied. Surrogate models of senior managers encompassed both the future state of the organization and work that needed to happen to prepare for and align the organization to this future. They made and justified decisions on the basis of this vision, which I coded as feedforward control. The instances of control at Suntown were directed at a major reorganization project, while at Fogtown they were directed at cost savings in infrastructure maintenance. This discovery prompted an additional course of interviews where I gauged how people thought about and responded to these instances of control by senior managers. Some of the themes that emerged were disgruntlement, surprise, and a breakdown of collaboration, for example acrimony between metering and distribution staff. In one case a distribution operator blamed meter specialists for not giving them new meter stock to make replacements and blocked his phone calls. City council members also received calls from customers who realized their neighbors had not paid for water in years because of a broken meter and enterprising meter specialists who found work arounds to fix broken meters "because it's much more interesting than just reading meters all day." At Suntown important courses of action included how superintendents won approval for a major departmental reorganization from the city's HR department. As one superintendent explained, “This is the first time in our history that we’ve ever justified a re-org on the basis of technology. It’s exciting! We’ve got to get ready for AMI!”

Selection. The last anticipatory phase I analyzed was selection. Here I hoped to understand how the preceding phases would come to bear on each agency’s procurement process and the eventual material composition of their AMI systems. I had two related units of analysis: the group that was tasked with selecting the technology, and the technological system itself. At municipal governments selection occurs through public procurement processes in which contractors bid on available contracts. Cities can select technologies and contractors in one of three ways: through a request for proposals (RFP), in which decision makers can weigh cost as well as quality of the proposal; through a “low bid” process, in which the city is legally required to accept the cheapest proposal that fulfils minimum standards; or finally through a direct purchase through a vendor with which the city already has a contract. I analyzed the way in which predictions and anticipatory action shaped the selection process at each organization. I was interested, for example, in the agencies’ ability to attract bids, and the quality of the bids they received.

The data I analyzed for this chapter was comprised of my observations of both agencies’ section processes, interviews, and all procurement-related documents. Procurement processes produce a great deal of documentation, much of which is available to the public. Selection involved the design and approval of bidding documents in a process that was heavily facilitated by consultants, and then receiving, reviewing, and scoring bids as a group. After scoring, agency staff and consultants interview contractors, select a winner, and then finally negotiate a contract. As stewards of public funds, agencies must meticulously document their decision processes in case of challenge. Thus, I had a trove of procurement documentation to analyze from both sites. Both agencies conducted their procurement exclusively over video platform, so whether I was physically at Fogtown or Suntown, I was able to observe the process at both sites. I additionally attended several informal lunches and small celebrations to mark milestones along the way.

Because I was interested in how earlier predictions and experiences shaped the specific desires for technical components, I conducted a round of selective coding for references to past experiences and goals for the technologies. I additionally selectively coded for each component of the AMI systems, as each agency dealt with each component in distinct conversations and areas of work. It was at this time that it became clear that the two selection processes at each agency were very different. Suntown pursued a traditional request for proposals (RFP) approach, while at Fogtown the group reached several crisis points and took a much more unorthodox approach to selection. Thus, in Chapter 5, I divide my analysis into two distinct parts, as two standalone explanations, rather than forcing a basis of comparison that did not hold out in my analysis.

At Suntown, it was clear from my observations that the members of the AMI working group were thrilled with how competitive their RFP process was, and used the interview process to push contractors on agreeing to specific technical demands within their RFP. Here my selective coding helped me isolate specific instances of creating and enforcing technical requirements that were justified by the group's reorganization and experiences during anticipation. The specificity of their demands surprised contractors, who often remarked at how informed city representatives were compared to their experiences with municipal bidding processes. Suntown approved a “turnkey solution” for a competitive price that they felt met all of their needs.

In analyzing my selective coding of technical components in the data from Fogtown, clear themes of disassembly and reassembly emerged. Rather than pulling each component together in a unified procurement, people at Fogtown separated each component into a distinct procurement strategy. I was surprised by this, and my interviews with their consultants suggested that this approach was very unusual but also very promising, given the difficulties Fogtown faced with getting the project to completion. I isolated each component and coded for the categorical procurement approaches that the group used to acquire it. I also coded both their plans and actions for putting the system back together on the other side of the procurement process. For example, Fogtown took an unorthodox approach by putting the AMI installer contract out in a low bid process. They received a low number of bids at a much higher price than they expected, and were forced to accept an installer contract that they were unenthused over. They sourced some components through direct procurement in a process that several described as “backing into” their technology selection.

Summary

There comes a point in any ethnographic study when the researcher has to ask herself whether it is time to leave the field. The problem with longitudinal studies of technologically induced organizational change is that it can at times seem like there is no end to the phenomenon that motivates our study. While things may come to seem predictable and through memo writing we seem to arrive at theoretical saturation, there is always the promise of another phase ahead. After selection, then adoption, implementation, and use! At several points during my data collection I asked researchers at my own and other institutions when they knew it was time to stop. One senior scholar suggested I read Hunter S. Thompson's book about the Hells Angels motorcycle gang, and told me that "Thompson knew it was time to leave when his informants beat him up and his life was in danger. That was a good sign for him." I, fortunately, was never really in danger during my research, but I was able to find my way to the end of the selection process and reluctantly extract myself from data collection. I say reluctantly, because I still get phone calls every week from informants who want to share a funny story or a tidbit they think I would want to hear about. While the work of water management and the transition to AMI is still underway, the way in which anticipation shaped the materiality of the eventual AMI systems was an important conclusion to my study. But I say this to emphasize my hunch that anticipation is at work in organizations all the time, and that perhaps any researcher with an eye towards future events could pick up on it within their own data. I have learned that an ethnographic study is an important approach, so as to be able to observe all manner of predictive activities and their implications for organizing and materiality. I would not have been able to catch the jokingly pessimistic side comments about the future or witness the despair when a project was blocked by management had I not been on site and embedded in the organizations I was studying.

III. Early Anticipation: Developing Predictive Technological Frames

Technologies do not appear at organizations unannounced. Long before implementation, people in organizations have means to hear about, interact with, and develop opinions of technologies in ways that affect not only what technologies are eventually adopted, but how they are used. The interpretations developed during this period about what technologies are and what they are for are important because they become part of a group's shared understanding of the future (Faraj & Sproull, 2000; Faraj & Xiao, 2006). Many have written about interpretations of new technologies as a kind of frame. Frames are a sensemaking structure through which we see the world. Regarding sensemaking within organizations, Goffman (1974) defined frames as flexible "principles of organization which govern the subjective meanings we assign to social events" (p. 11). Individuals develop frames as part of a process of sensemaking, but framing is also a social process that is shaped by interaction with others (Weick, 1995).

Technological change is one process during which framing often occurs. Frames of technologically induced organizational change are called *technological frames*, which Orlikowski and Gash (1994) have defined as a "core set of assumptions, expectations, and knowledge of technology collectively held by a group or community." It is widely understood that "the initial stages of framing a technology are formative in the ongoing interpretive process by which individuals give meaning to the technology and develop a trajectory of use for it in a particular setting" (Cornelissen & Werner, 2014, p. 200). The framing of digital technologies is of particular interest to scholars and practitioners alike, given the technologies' potentially disruptive and complex effects on organizations (Spieth et al., 2021). Scholars have demonstrated many of the effects of frames on people and organizations. But whether they are incongruent with other people's frames (Leonardi, 2011b; McGovern & Hicks, 2004), congruent and shared by others (Davidson, 2006; Mazmanian, 2013), or ambiguous (van Burg et al., 2014), we know little about how frames actually develop and change over time. Davidson (2006) suggested that given how highly cited the concept of technological frames is, the fact that it is still lacking in processual explanation is evidence that the concept has fallen victim to "theory as slogan" (DiMaggio, 1995). As a remedy, reviews on the topic have called for longitudinal studies that can uncover how frames change over time, producing more generalizable mechanisms and explanations and a more clear processual view of the phenomenon (Cornelissen & Werner, 2014; Davidson, 2006). In this chapter I contribute to the literature on technological frames by considering the influence of non-users in the framing process and means of interpretation that do not rely on interactions with the material artifacts themselves.

Most studies of technological frames have looked to interpretations made by technologies' users (Davidson, 2006; Kline & Pinch, 1996; Leonardi, 2013a; Orlikowski & Gash, 1994). Users begin to frame a technology when they get their hands on prototypes, attend trainings, and collaborate with one another to figure out how to make the best use of a newly acquired tool (Anthony, 2018; Kaplan & Tripsas, 2008; Leonardi, 2011b). Studies of technology use have been the basis for proposed typologies (Mishra & Agarwal, 2010) and measurements (Schneider & Sting, 2020) of technological frames. While users were clear agents in the framing process, they were not the only or even the first people involved in shaping how people in organizations understand the purpose and benefit of a new technology. Early scholarship on frames, for example, recognized that the frames held by managers are likely to be different from those of users (McGovern & Hicks, 2004;

Orlikowski & Gash, 1994), but beyond analysis of the effects of discordant frames, it is unclear how managers develop their frames in ways that are different from users. One factor may be the degree to which people interact with the material artifact itself, as most research on technological frames centers on people's interaction with the technology. This is the case for many different types of technologies, including software for collaboration across groups (Orlikowski & Gash, 1994), mobile email devices (Mazmanian, 2013), or open source software (Barrett et al., 2013).

There is a range of ways in which interactions with material technologies shape technological frames. One distinction is the degree to which people black box a new technology when they first acquire it (Anthony, 2021). For example, Vaccaro et al. (2011) found that when designers acquired new components to incorporate into their automotive design process, differences in the granularity of their interaction with the artifact related to and helped shape their product design goals. A coarser level of interaction was associated with goals of cost reduction and faster design-to-market timelines, while a more granular engagement with an artifact supported greater product differentiation and quality. In his study of the incongruent frames developed by auto engineers, Leonardi (2011) found that the differences between user groups stemmed from their understanding of the problem that the technology was meant to solve. Their frame of the problem the technology was meant to solve shaped their subsequent use practices in ways that reinforced their initial frames. His study of engineers unearthed the way in which "innovators are blind to the fact that others have constructed different problems than they have" (p. 350). Similarly, when different user groups experience variable process outcomes from their use of new technologies, their interpretations of those outcomes can contribute to incongruent and discordant frames across user groups within an organization (Young et al., 2016). These mechanisms are not applicable in the case of selectors. Not only do selectors have little to no interaction with the technology itself, but they are not the end users. Instead, they select and procure new technologies for use by others. Thomas (1994) emphasized that especially in hierarchical organizations there are important distinctions between selectors and users of technologies as one moves up or down the organizational hierarchy. People in different positions within an organization rely on different frames, or worldviews, to shape their understanding of what a technology is and how it will be used. The power-process theory Thomas developed to explain these distinctions is political in nature, and a full understanding requires going beyond a focus on only managers, or even the end users themselves. In the latter case, he argued that research focused on the end users typically portrays users' involvement in change processes "as reactions to initiatives originating elsewhere in the organization" (p. 27). Decades have passed since Thomas elaborated on the significance of decisions within the overall change process, but our understanding of the people and groups who make decisions in the early stages of a technological change process is still undeveloped. The people within an organization who initiate the change process and begin to select a type of technology make decisions, and,

> …indeed, the "texture" of the decision process is a critical part of the story: the bumps, the rough spots, and the detours all may contain vital clues for understanding how technology is given meaning and purpose. (Thomas, 1994, p. 31)

If decisions in early stages are important, who are the deciders and selectors of technologies within an organization if not the users themselves? How do they initiate the technological change process absent interaction with the material technology itself? Despite the rich evidence of the importance of the interaction with material technologies, we have comparatively little to guide us in a study of other forms of interpretation and technological framing by managers, non-user champions, and other technology selectors.

Only recently has scholarship begun to identify some ways in which people develop frames without interacting with the material artifact itself. An example of interactions around (instead of with) an artifact are rumors in advance of an anticipated product launch. Seidel, Hannigan, and Phillips (2020) explored this phenomenon in their study of the spread of rumors on social media about upcoming product launches. They found that online rumor communities fed off leaked information and educated guesses to shape technological frames long before firms reveal product to the market. Designers incorporated rumors about components and capabilities into products to meet the built up expectation in the market. Rumors-shaped frames are of interest to the firms themselves, such that the frame produces a performative feedback loop when designers update products to include facets that received attention online. A limit of product development studies, however, is that they have encompassed framing on the design side of the technological change process, looking at the "prehistory of the product" (Kirsch et al., 2014) rather than use. In contrast, I contribute a study of technological framing in advance of technologically induced organizational change. In this chapter, I ask how people in the adopting organizations develop frames in advance of adopting a technology. To solve this puzzle, I focus on the interactions within the organization in advance of selection and implementation. In this way, I can assess how people gather and process information about a probable future technological change and work together to produce a shared frame that supports collective action. In this chapter I show how two organizations developed technological frames about a set of digital transformation technologies years before implementation. I contribute a set of generalizable constructs and expand our understanding of the process of developing technological frames within organizations.

Trajectories of Predictive Framing

In the early days of AMI's introduction to Fogtown and Suntown, people at each organization tried to understand in advance what it would be like to transition to a new metering system. Many other agencies had begun to transition to AMI systems. Over time and through their actions, people at Fogtown and Suntown developed a sense of what AMI technologies were and how they could be used in their own organizations. While a few interacted with the physical technologies during piloting, most learned about AMI from their colleagues and contacts outside the agency. Information they acquired gave texture to their predictions of their organization's future with AMI. In this chapter, I explain the ways in which people first developed predictions of how AMI would be used in the future.

The period analyzed in this chapter begins with the organizations' first encounters with AMI technologies and ends with project approval from the agencies' directors. For the people engaged in the early stages of technological change, predicting was an ongoing activity. They altered and developed their predictions with access to new information. Once a project was approved, the project and thus the shared predictions seemed much more probable, such that the accepted predictions at the time shaped actions that influenced the subsequent selection process. In later chapters I analyze the ways in which predictions informed anticipatory action and control by senior management after they approved the projects, and how both prediction and action later shaped the technology selection process.

The process of introducing AMI to the water agencies lasted several years. During this period mid-level managers worked together to attempt to understand and introduce the new technological system of AMI to others in the organization. Anticipation began with the first contact with a new technology through hearing about its use in other agencies. Action during this period shaped how the new technology was first introduced to the agencies more broadly. The general model of the introduction period is below in Figure 3.1:

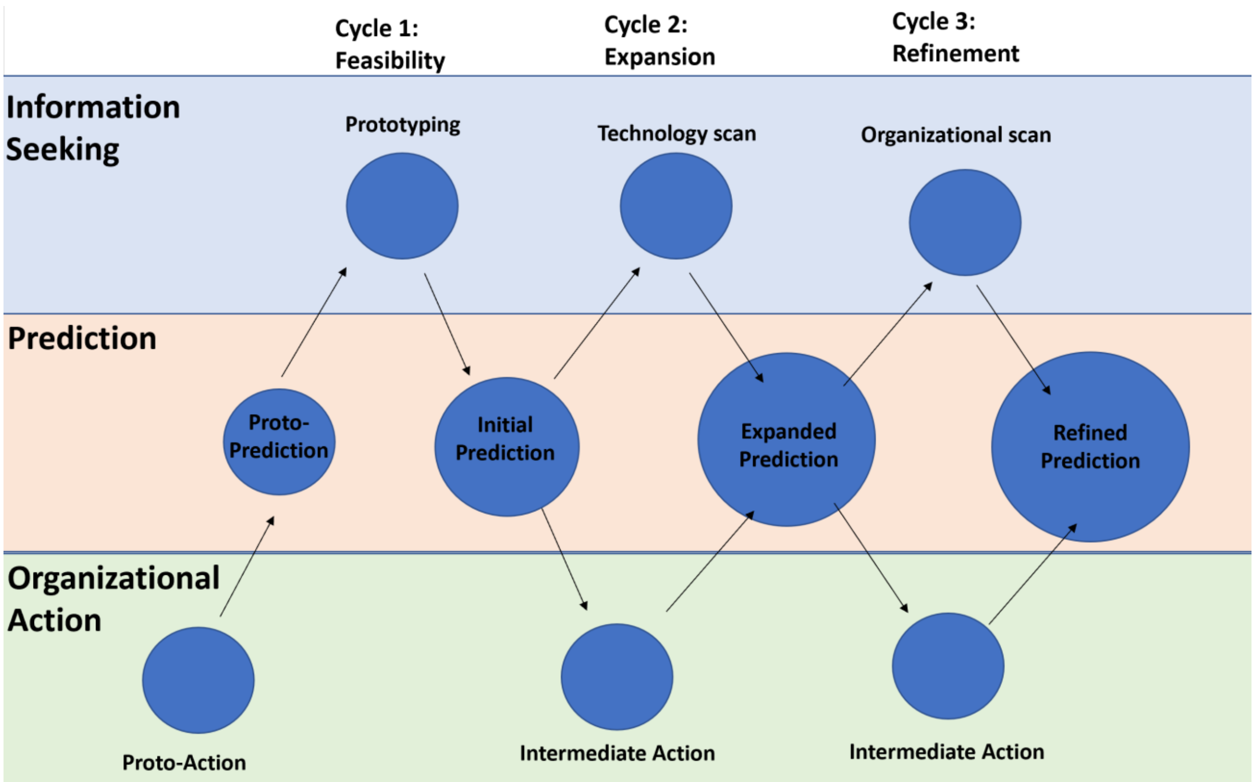

Figure 3.1. Prediction and Action During AMI's Introduction at Suntown.

Activity sequences moved between three levels of activity. In general, activities were the outreach efforts, research, discussions, communications, and decisions that workers and mid-level managers made during their effort to understand and introduce AMI to their organization. On the bottom level in Figure 3.1, "organizational actions" were actions that effected changes in a material infrastructure or organizational structure. Upgrading mechanical meters to digital ultrasonic meters or hiring new temporary staff to survey the meter stock are both examples of organizational action. These were formal decisions that required funding and official sign off. In the middle level of Figure 3.1 is prediction. “Prediction activities” were activities that led to shared predictions. Examples include discussions about the future in meetings, phone calls, or interviews, but also statements made in emails to colleagues and written updates in newsletters that expressed a prediction of the technology. At the top of Figure 3.1 is information seeking. These were instances when people sought out information from outside the organization. Inquiring phone calls made to colleagues at other agencies, research solicited from consultants, and pilot programs are all examples of information seeking activities. Both organizational action and information seeking shaped prediction in the center level. As the organizations progressed through sequences of action and prediction, their shared predictions changed, either by becoming more expansive or more refined.

Organizational Action

At Fogtown and Suntown, organizational action encompassed one of three types of activities during the introduction period. As already defined, organizational action was action that altered the organization in some way. Organizations took actions that altered the context and thereby wittingly or unwittingly affected their later assessments and predictions about adopting and/or using AMI technology. Importantly they may or may not have understood this at the time the organization took these actions. Actions could alter either the material or the digital infrastructure and both have important consequences. At Suntown, for example, when mid-level managers had to pause their AMI activities to respond to a worsening drought, managers decided to replace their entire meter system in preparation for a later transition to AMI. Their organizational action altered both the physical infrastructure in the service area and the nature of the organization's readiness for change. They chose meters that were AMI compatible so that they would have the option to transition to AMI once the drought subsided, rather than waiting 20 years until the next meter replacement was due to implement the new technology. Most utilities upgrade to AMI at the same time that they replace their meter stock. Suntown's workgroup decided to install newer versions of the same mechanical meters in place that came with an analog-to-digital connection that could support an AMI endpoint in the future. A member of the AMI workgroup summarized the separation later as a first step forwards in a meeting:

> Our next effort is for AMI, which is basically "smart meters." We have gone through replacing all 27,000 meters in our system, which we'll finish up this year. These meters are capable of communicating remotely. Now the last piece of that is actually installing the technology that will communicate back to a central hub.

The new meters were a hybrid between mechanical and digital options on the market. They chose mechanical meters despite the fact that there were new meter technologies on the market that measured volume in new ways, so that the City could delay a transition to digital until the technologies were more proven.

Action on digital infrastructure was similarly consequential. In the following example, a customer service manager at Fogtown named Evan talked about changes he made to the City's billing system and a related software program in recent years. The agency had long used a program that had been built in house decades earlier. The program was very limited in function, and Evan wanted to upgrade to a system that allowed for easier online bill pay, hoping it would reduce customer traffic into the office and the time-consuming process of taking payments over the counter. He explained how difficult the experience had been:

> We've just migrated to a new online bill pay platform. We invited 13,000 customers to the new platform, but it's been a fucking pain. We moved anyone who had a profile on the old platform, meaning they had a credit card on file, to the new one. It's been a real headache because the invitation went to the email on file and some people were on autopay and set it up years ago and that email is dead. Some couldn't get into their profile, and some had their credit card expire, so then the payment didn't go through. We've had all kinds of issues with it. It's getting better, but transitions are scary. It was bad.

Evan's complaints demonstrate how fraught organizational action could be when digital technologies were involved. Agencies like Fogtown and Suntown used several digital software programs to manage, track, and bill customers for their water consumption. Changes to those systems impacted the staff who interfaced with them and customers who relied on them to pay their water bills. The example from Evan about the billing system is important to the City's AMI project, because people had to decide when and in what order to upgrade software that they would later integrate with the new metering technologies.

In the lead up to adopting AMI, people took organizational actions that affected software, physical infrastructure, and the organization of work. These actions affected conditions for subsequent predictions for technologies. For example, Suntown's meter replacement gave the AMI group flexibility in the AMI project's timeline. They could choose to move slowly if they needed more time, given that the meter stock were in good shape and did not need replacing for another two decades. They could also move quickly if they knew what they wanted, given that replacing meters was the most labor-intensive part of the upgrade, and with those already in place they could more easily install AMI transponders. Hypothetically, if they had delayed the meter replacement portion of the project, they would have had to deal with failing meter stock at the same time. This flexibility gave them confidence to pursue their ideal AMI system. In contrast, Fogtown's negative experience with the billing system upgrade made them wary about the AMI upgrade. Evan's anxiety about the action of upgrading the bill-pay platform later made him similarly hesitant about upgrading the billing system for AMI. To answer the question of how shared predictions of technologies emerged at Fogtown and Suntown, it is necessary to contextualize sequences of organizational action taking place. A second area of activity that influenced prediction was information seeking.

Information Seeking

The purpose of information seeking was to bring new information into the organization from beyond its formal boundaries. In the following example from one meeting, a group of Suntown people attended a demonstration of a Customer Engagement Portal, or CEP. CEPs were one of the five components of an AMI system, and agencies could procure one of many CEPs on the market. Roy was a representative from a CEP firm, and Peggy and Juliette asked him questions during his demonstration:

Peggy: My only question right off the bat is can we add new customers to the system ourselves and do we have to look for you for that?

Roy: Yeah. So the time being, you'll go through us. It's super easy. I can do it at the drop of a hat. But for the time being, it'll go through us. Okay. Cool. Well, this is the training portal. I have a link for it on the pdf as well. I'll send the link—

Juliette: Before you go there, I wanted to confirm for the customer portal, it's really designed primarily for residential customers, correct?

Roy: That's correct. Yeah. We have found that it is an advantage that it's almost exclusively for our residential customers. We have found that there are some commercial customers that like to have the data readily available, but some of the levers for commercial accounts are very different from those of residential accounts. It's very difficult to compare commercial accounts without a little bit more acuity or granularity. You know, a burger joint is very different from a car wash which is very different from a hotel.

In this meeting, Peggy and Juliette were already well-versed in customer portals, and they came prepared with questions for Roy and interrupted him throughout. They used the demonstration to see the product in action and gain a better understanding of whether it could help them meet their goals for communicating with customers once they had AMI data available from the new system.

At Fogtown, the AMI workgroup tended to look close to home to gather information about digital metering systems. They did not do as wide a search as Suntown. Mick, the meter shop supervisor, talked about ways he learned from neighboring agencies when he transitioned the city from manual to Automated Meter Reading (AMR), an earlier technology than AMI:

> Around here I think Bufordville was kind of the trailblazer when it came to AMR. They gave a presentation a bunch of us saw at a regional conference at one point. We followed shortly after. But between Bufordville and us, I think every, all the smaller agencies around here were more "wait and see." When Desert Valley and the university went to an AMI system, I'm the one that set up a demonstration of that system over here for us.

Mick's recollection of the transition to AMR was similar to how he had approached the upgrade to AMR a decade earlier. The agencies he mentioned were all neighboring service areas that operated within the same watershed and with a similar service area as Fogtown. Mick saw that they had positive experiences moving to AMR and then AMI, and he learned from their experiences at conferences and through demonstrations that he organized. Like organizational action, information shaped people's predictions about AMI.

Prediction

Information seeking and organizational action influenced predictive frames of the technology in the middle plane of Figure 3.1. Each sequence's frames shared three common predictive dimensions. First, predictions had a temporal horizon, which gauged whether the change and its effects would be realized soon or in the more distant future. Second, predictions sketched out the boundaries of the applications of the technologies. A narrow application meant limiting the technological change to metering, while a more expansive interpretation included applications of the data from AMI in other departments of the water division. Finally, predictions included an estimation of how much organizational change would necessarily accompany the technologies. In the following example, George, the Water Resources Manager at Suntown, described his prediction of how the agency could use AMI and how it might affect staffing:

> I think there's a lot of pressure to reduce staffing and reduce costs, and I just think that unfortunately, or fortunately, with AMI I got ahead of it early enough to start telling the community and the city council that I just don't see this as being a labor force reducer at the end of the day. And unfortunately there were some agencies who got out there and said, "This is going to reduce the size of our staff," and I think they're finding that's not what's really going to happen.

George's prediction in this example encompassed new areas of work made possible by AMI interval data, and also his prediction differed from other agencies who characterized the technology as labor saving. Recent information that George had gathered from other agencies who had fully implemented AMI systems and from consultants influenced his prediction that he would likely need not only the same number of metering staff in an AMI system as a manual one, but also would need staff with more advanced data analytics skills to make use of the new system. A table of both agencies' predictive technological frames during AMI's introduction is in Table 3.1.

Table 3.1

Predictive Technological Frames

Prediction	Suntown	Fogtown
Proto-prediction	Prognostic *Could improve metering*	Diagnostic *Could solve metering problems*
Initial prediction	Application: Narrow *Metering system* Temporal Horizon: Moderate *Within a few years to install* Organizational Change: Unclear *Need more research into meter readers' role with AMI*	Application: Narrow *Metering system* Temporal Horizon: Short *Within a year to install* Organizational Change: Minimal *Contract out installation work*
Expanded prediction	Application: Moderate *Metering, Billing, Conservation* Temporal Horizon: Long *Several years of learning to use data* Organizational Change: Moderate *Meter-to-cash people will need to work together more*	n/a
Refined prediction	Application: Broad *Water loss tracking, water rates* Temporal Horizon: Long *This is just the beginning* Organizational Change: Broad *Rethink how customer service is organized*	n/a
Factors that explain differences between predictions	Delays to project were "acts of God" Greater access to external networks Early high-status buy-in Metering system functional	Delays to project were political Fewer contacts outside organization Metering projects considered low-status Metering system in crisis with immediate needs for repair

This table gives an overall picture of Suntown's progression through multiple sequences of activities that produced more expanded and longer-term visions of change. Fogtown, held back by acrimonious political roadblocks, did not continue to expand or refine their predictions of AMI and as such remained more limited in their predictions of AMI's applications. A key explanatory factor was Fogtown's error-ridden digital metering system. People cultivated a sense of urgency to solve the metering problems quickly, rather than undertaking a slower, more deliberate, and research-based approach to change. In the following sections, I explain the way in which shared predictions evolved and changed over time as people progressed through sequences of action.

Trajectories and Sequences

The pattern of activities during AMI's introduction was similar at each agency. People worked together in AMI workgroups to gather information, take organizational action, and make shared predictions about AMI. Their activities progressed through similar sequences that produced changing predictions. For both sites, the first sequence was a feasibility sequence, in which people tested out and understood if the technology would work in their organization. Suntown progressed to a second sequence of expansion in which they built out their understandings of the technical options and configurations that were possible with AMI systems. A third sequence occurred at Suntown in which they refined their predictions to incorporate information about organizational change. In contrast to Suntown, Fogtown's trajectory was cut short when the AMI group's progress was blocked by a hostile political environment. Thus, the Fogtown AMI group only completed the feasibility cycle, and they did not expand or refine their understanding of the technology or the necessary overall organizational change that might accompany it.

Sequences of organizational action, prediction, and information seeking were led by project champions. In interviews and observations people could quickly point to the person whom they perceived to be the most knowledgeable about the technology and who was responsible for leading the effort to bring it to the city. Champions gathered others around them into ad hoc and standing AMI workgroups for the duration of the introduction phase. For example, Manual, a long-time engineering contractor for Suntown who was assigned to the AMI project, said, “to me in my work, Peggy is one of my stakeholders. She originally started this process of the AMI implementation a long time ago, and it’s kind of her baby.” At Fogtown, people looked to Mick’s boss Evan, the customer service manager, as the project’s champion. For example, Jill, a conservation coordinator, said, “It’s hard to keep track of the whole AMI project, but Evan’s taking the lead on all of that.” Champions at both Fogtown and Suntown developed an understanding of how AMI technology worked, and they felt strongly that it was important that the agencies adopt the technology. The role of champion was important because the decisions that they made and the way in which they introduced the technology, learned about it, and recruited others to get involved shaped the way in which a dominant prediction for AMI emerged in each organization. I describe this process during each agency’s introduction periods and explain why they differed in their trajectories and outcomes, beginning with Suntown.

Suntown’s Introduction

Suntown’s introduction period consisted of three activity sequences. Suntown’s AMI workgroup began with a proto-prediction that AMI could be good idea for the metering system. This early sense shaped an initial pilot program during which they deployed a small number of AMI units in their existing system. External events slowed down the project, but in the meantime Suntown pursued intermediary organizational action and further information seeking activities to produce a more expansive and refined prediction by the time the project received approval.

Sequence 1: Feasibility. During Suntown's feasibility sequence people gauged the pros and cons of shifting from a manual metering system to an automated and digital AMI system. The shift was a big change for Suntown. Unlike many other agencies, Suntown had refrained from adopting new digital metering technologies that had become available in the last decade. Their system was based on mechanical meters that are read manually by meter readers. Thus, a transition to AMI would be a major jump for the city, and Suntown's people proceeded with both openness and caution to produce their first predictions.

Proto-prediction to Information Seeking. When Peggy learned about AMI around 2011, she had recently been promoted to distribution supervisor. In her new post she was responsible for the meter shop, which was staffed by four meter readers and a lead meter reader. She approached the position with an openness to change. The distribution supervisor who preceded her was deeply disliked by the meter staff, and the meter readers had suffered under his hard-driving management style. Several meter readers were recovering from repetitive stress injuries that resulted from the physical work of opening meter boxes and reading as many meters as the supervisor demanded. Overall, the shop suffered from low morale, and one of Peggy's first acts as supervisor was to give more power to the lead meter reader to make a less physically taxing reading schedule and to assess the state of the metering system for improvements overall. Eager to learn more about metering so she could better manager the metering staff, she gained permission to attend regional conferences to get up to speed on her new responsibilities.

At one of her conferences she learned about AMI and was interested in it and how it could improve work in the metering group. Peggy was interested in the new technology, but she and her superintendent David shared a skepticism about the promises of new technology. They were eager to advance technology in the division, but they had seen negative press coverage of water agencies that moved too quickly into a new system. Peggy often brought up one city's embarrassing episode of overcharging many of their customers as a consequence of collecting and billing for incorrect meter reads. In an email to colleagues, she forwarded a news story and included her own comments in a reply: "did you see that news story I sent you about [Center City]? They overbilled thousands of customers! Disaster!" Throughout the early anticipation period, Peggy and her supervisors were wary of firms overpromising and underdelivering on technology.

David drew on his experiences with deciding among new meter technologies that offered alternatives to traditional mechanical disc meters. David's involvement was important because as a superintendent, he was Peggy's superior and she needed his blessing to pursue the technology any further. David summarized his perspective on much of the new technologies coming out in water management:

> There's definitely an element of us having some skepticism about what companies tell us about their products. We've tried several different metering technologies, just the meters themselves, over the last 10 years, and some of them have been OK and others have really not shown the success that we would want. They fail within five years of installation, or they don't have all of the features they promised, or they are not as maintenance free as advertised. So as far as looking at the evolution of the metering group and the skill sets that are needed I think we are going to continue to become more and more technical, but we have to be wary of the overpromise and underdeliver aspect of things. With AMI, sure you get all of this data, and there's lots of things being pitched about what you can do with that data, but there's still a whole lot of development that has to be done before you can really feel confident that it works. Water systems are complicated.

David's response shows how he and others in the division were eager to advance technologies in the water system, but they felt the responsibility to proceed carefully and verify the performance of any new technology they would adopt. Peggy and David both wanted to see the technology in action and sought resources for a pilot program. To run a pilot, they needed several hundred AMI transponders that they could attach to their meters, a data collector unit for the radio network, and access to a temporary software license for both the customer-facing Customer Engagement Portal (CEP) and staff-facing Meter Data Management System (MDMS). Peggy's hope was to eventually try out both the cellular and radio network options and see how both her staff and customers used the new system. Peggy explained:

> I did a grant proposal way back in 2011 for a small AMI pilot. It was me and the head of water conservation at the time that pushed to get it started. That started the buy-in, but folks realized its usefulness quickly.

Peggy's plan for the pilot was to enable her, her staff, and her superiors to gather hands-on information about AMI. In the early days of piloting the radio network, she reported that its usefulness was quickly apparent to others. Launching and learning from the pilot was the agency's first act of information seeking.

From Information Seeking to Initial Prediction. Peggy's experience with the first pilot was positive and she was encouraged about the potential for AMI at Suntown. Because her first pilot had only tested a radio network, Peggy was curious about what other kinds of AMI systems were out there. She was particularly interested in trying out other network options after running into some problems with the radio pilot:

> [SharpBeacon] had a little out-of-the-box starter tool kit, kind of a promo thing that they were offering us, that was a very attractive price point, and we wanted to try both cellular and fixed [radio]. Plus at that point we wanted to see other radio products, because we had chosen MeterSmart just because we were already using them for our

> limited AMR meters and our handhelds. We just had a lot of their software on those things, and so the idea was that it was supposed to be easier to set up a pilot with them because we already had infrastructure on the ground. For the pilot we just had to put up the data collector, but [laughing] that didn't always work so well!

Peggy's initial prediction was that AMI had more variables than she could consider with only one pilot. She did not yet understand enough of the nuances of the system to make a call on the direction the city should go with regards to radio or cellular networks. She saw a long-term project ahead that needed more research into the technical components. In a customer service meeting, Peggy talked about the technology with George, the director. Peggy emphasized AMI's complexity in a side conversation as the customer service meeting was ending:

> Automation is just a small piece of the pie and there are a lot of other slices which is why doing engagement activities is so important. When I discuss [AMI] with people they're like oh that's your water meter thing. Yes, it's a device we're attaching to water meters, but water meters matter for billing!

Her initial prediction was that the technology was more than a metering technology, and that to realize its wider applications and be successful they needed to understand how the system would integrate into other existing systems at the City. Before Peggy and her team could move forward and take action, they were held back by external events. A historic regional drought intensified and Suntown's supply was at a crisis point. Senior management made the decision to direct funds and staff priorities towards drought response, and Peggy pivoted to identify intermediate steps for AMI until the drought subsided. Her guidance during the drought expanded hers and others' sense of AMI technologies.

Sequence 2: Expansion. After assessing the feasibility of AMI in the first sequence, Peggy and her collaborators were intrigued by AMI's potential. The technology seemed useful, but they had more questions about it than before they had started. They no longer saw it as just the automation and digitization of their metering system, but also a data-producing system that might affect the work of billing and possibly other departments in the division. The drought slowed them down, but, as Peggy put it, "There's always going to be something. We can't wait to do this or we'll never get there." Thus, rather than waiting, she and her collaborators worked to reimagine and expand how they might implement and use an AMI system. In the second sequence, called *expansion*, Suntown's ad hoc AMI group that included Peggy, David, and Juliette from Conservation progressed through a second round of information seeking and organizational action to produce a more expansive prediction of AMI and technological change.

From Initial Prediction to Action. The group had ambitions to take what they had learned and build a better AMI system than the ones they had seen. The drought presented a challenge to the momentum they had built, but they enjoyed the challenge. Rather than waiting for a less hectic time to take on such a big technological change, Peggy and David especially pushed each other to work harder to move the project forward, drought or no drought. As David described their work during this period:

> There's just a lot of ideas and big thinking that's coming out of this because we're getting big data for the first time… we would really like to make sure that we get ahead of the implementation.

The idea of "big data" was exciting, and they saw AMI as their first opportunity to get their hands on it, even if they were not sure what it meant yet. Where most agencies looked at implementation as the time when they would get to know the technology and how it worked, Peggy and David wanted to get out ahead of it.

One issue facing them was the need to replace the small meters in the service area. While the standard approach for AMI was to install it when an agency replaced its meters, David proposed breaking the process in two. First they could replace the meters, and then once it rained and the reservoirs were out of danger, they could move forward with AMI. Thus, for the organizational action in this sequence David led a major initiative to replace the City's small meters. In the meantime, Peggy headed up the information-seeking effort. She worked with consultants and industry associations to continue to research other technologies on the market. In this effort, Peggy was exhaustive. She went beyond agencies in her region and sought out AMI projects on the other side of the country with totally different climates.

Both courses of action lasted several years and both changed the organization and produced new information and experiences that people could draw from to build out their predictions of AMI. Peggy explained to colleagues in an interdepartmental meeting:

> After the drought slowed us down, we initiated replacement of meters. We weren't sure of the AMI tech then, but we knew we needed to replace meters. We kicked off a program to put in AMI capable meters. They have a little umbilical cord to connect to AMI endpoints. We've replaced 96% of our meters with city staff and hourly support, and it has stabilized some of our internal water loss.

Peggy's description highlights their decision to install AMI "capable" meters, but also the effort of using salaried and hourly city staff to accomplish the project. This was a slower approach than hiring an outside firm to complete the work, but they were not in a rush during the drought years. The decision to separate a meter upgrade from the AMI project had two key outcomes for Suntown. First, it freed them to take more time to leverage their access to the institutional environment and gather more information about AMI technologies. Having replaced the aging meters, the metering infrastructure was no longer a pressing concern. Peggy and David continued to develop an understanding of the technologies as they progressed through sequences of information seeking, organizational action, and prediction. Second, it allowed them to divide the project into two types of materialities: One was the physical meter infrastructure replacement, the other was the digital upgrade to AMI. Meter replacements are expensive, complicated, and time consuming, and when AMI is paired with meter replacement, the new technology can seem like an add-on to the bigger physical infrastructure project. With new meters in the ground, Peggy and her team were able to focus their and others' interest on the digital nature of the technology it produced. This enabled them to explore applications of AMI data in more expansive ways that increased the status of the project over time, of which the second course of action was a major part.

The second course of action shaped by Suntown's initial prediction was information seeking. The focus of this phase of information seeking was to learn more about the components of the AMI system. The pilot had sparked Peggy and others' interest in not only the type of network, but also the many other components of the overall system, including the Meter Data Management System, the headend system, the customer portal, and the data integration between these and their already established systems. The primary avenue through which Suntown's AMI group gathered information was their membership to an industry organization called SURF. SURF was a consulting consortium with an international member network of water utilities that provided support to member utilities to navigate the market of technology innovations in water management. David saw the relationship as an important part of improving work at the city more broadly:

> One of the things I've been brainstorming is having more of an innovation culture. SURF has been really helpful for us to have a little bit of that. We're so busy and so slammed with existing workload. We have a backlog of maintenance that is a country mile. It is unfortunate but we're trying to find ways to deal with that and figure out how the city can adopt technology in a more program basis, or at least in Public Works.

SURF enabled the division to pursue new technologies without taking unnecessary risks. David was limited in his vision to make the division more innovative by budget and workload, but tapping into outside resources enabled him to leverage the insights and experiences of others. He looked forward to attending the regional SURF meetings and often shared learnings and impressions from those meetings with others. SURF held three regional meeting annually for utility membership.

At regional meetings SURF screened technology companies and, based on feedback from utility members, selected five companies to give 20-minute presentations with 15 minutes for Q&A. If the utility requested, they could be put in touch with the company afterwards, but if the utility was uninterested, the company would not follow up. After each presentation, the utilities had a few minutes to discuss the company on their own during a "utility-to-utility" discussion. David called SURF his division's R&D department, and at about $8,000 in membership fees a year, "it's much less expensive than trying to manage it all in house." He summarized its benefits on a phone call with another utility in the region:

> We have a membership to [SURF]. Through them we're networked and a lot of other agencies [in the region] and basically we get bombarded by vendors for all sorts of tech and it's tough because I'm a public servant and when they say I can save you money I can't ignore them. They want meetings, so we benefit from SURF because it's like Shark Tank[7]. Someone [from the firm] comes does a pitch in front of the group and after they leave the group talks about if they are interested in piloting that tech. Or if they have already piloted it—they can share their experience. We don't have our own innovation group, so this helps us a lot so we can try and stay innovative. It's my one thing I do at work that I enjoy both professionally and personally.

David and his supervisors regularly forwarded phone calls and emails from firms' sales representatives to SURF rather than dealing with them individually. This way, they were able to fulfill their due diligence as public servants, but avoid the responsibility of vetting firms on their own.

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[7] A TV show for would-be entrepreneurs

Peggy and David leveraged their access to SURF consultants and its utility members to learn more about AMI. One of the information seeking activities they referred to most often during this period was an “AMI technology scan” they requested from SURF. Consultants interviewed dozens of comparable utilities that had installed AMI and queried them about the technical specifications of their AMI system and their experience with it. The report included the following areas of inquiry in Table 3.2.

Table 3.2

Technology Scan Search Parameters

AMI Technologies	Meter Data Management (MDM) Technologies
Company	Company
Technology Readiness Levell (TRL)	Description
Description	Website
Meter Data Management (MDM)	Technology Readiness Level (TRL)
MDM Proprietary	Meter data storage capabilities
Communication Network	Data Analytic Functions
Hybrid AMR/AMI	Customizable
One Way/Two Way/Quasi	Compatible with [Suntown’s billing software]
Compatible with Existing Meters	API in Billing Software for Meter Data
Nicor Connector	Customer interface
Contracting (distributors, direct with vendor, both)	Meter and AMI agnostic
Customer service through distributor or direct with vendor?	AMI Vendors integration examples
What is the battery life?	Deployment (direct/subconsultant)
How many years is the warranty? Full or prorated?	Customer service model
Vendor: # US AMI Installations operating longer than 1 year	Water Experience
Distributor: # US AMI Installations operating longer than 1 year	# deployments
Customer Service Model	
Website	

The information in the technology scan was extensive and included implications that were unique to Suntown. For example, the SURF consultants ascertained which companies’ products were compatible with the Nycor connectors (what Peggy referred to as an "umbilical cord" when talking to her colleagues) that they installed during their meter replacement program that converted the analog measurement to a digital signal. From the report, anyone in Suntown's AMI group could learn more about the applications and limitations of AMI technologies on the market. The report presented AMI as a system made of many components within which there were multiple variations. For example, one of the insights from the report into one of the MDM components was:

> [ABCtech] is a tool set most notably known for their proprietary database best suited for capturing time series data from SCADA system. It is operations data management instead of meter data management so not a traditional MDM. They do not validate, edit, or estimate (VEE), and no meter to cash or meter to bill.

This summary let Suntown's people know that the software was marketed as an AMI solution, but in fact was better suited to a SCADA system, rather than a meter-to-cash AMI system. SCADA systems are cybernetic control systems that water production and distribution divisions use to track and manage water within a service area. SCADA systems manage water at the level of the pump station, rather than customer meter, and operate on their own highly secure proprietary network. SURF reported in this example that the system would not meet Suntown's needs for a meter-to-cash operation. Both forms of action, information seeking and organizational, influenced Suntown people's predictions about AMI.

From Action to Expanded Prediction. Information from information seeking and organizational action helped people at Suntown to expand their initial prediction of AMI's applications, temporal horizon, and need for organizational change. First, the information from the technology scan showed them that the applications of AMI were much broader than they originally perceived. Where the dominant prediction of AMI had been to automate and digitize the metering system, they now looked ahead to applications in other areas of work within the division. In an interview, George gave an example of the other types of activities they were imagining being possible in an AMI system:

> Right now we have five staff who go out every day and read [30,000] meters a month. So, a very physical job, they're out there walking in the streets, and the intent is to kind of gradually over the next 3–4 years move away from that and have these electronic readings where we're getting data every 15 minutes from every single meter in town so we know exactly where the water is going. That means if there's a customer who has a leak, we can reach out to them quickly and let them know so they can get a plumber out there and shut their water off and try figure out where the leak is, therefore reducing we think at least 5–10% of the city's water usage by being able to communicate more quickly our customers that there's something unusual with their water usage. So it has all kinds of implications as to our work practices, our billing system, questions about confidentiality. All kinds of interesting issues that come up with that information.

George's comment demonstrates a shift from predicting applications of the automation made possible with AMI to the implications of shorter interval data. Technologies used before AMI, whether manual or through AMR, only produced one data point per month about a customer's water use. This data point represented the total volumetric consumption over a billing period. With only one data point, people were limited in their ability to act on the data.

Leaks were difficult to identify in a timely manner in the current mechanical and manual system. By the time a meter reader visited a customer's home, a leak could have begun weeks before without a customer's knowledge. Fran, a water resource specialist in the conservation group, described the process by which they addressed leaks with monthly reads:

> So these [customers] called us. They got a door hanger because the meter readers noted that when they read the meter it was high. They also run a report in the office that says if the water consumption is extraordinary high. It could be double. It could be more. It could just be out of the norm. And the meter readers come back and reread it to make sure that there's not a, human error, which sometimes happens. So then they read it again, and if they confirm that the read is correct, they'll leave a door hanger. That's the first step. Because they won't get their bill for two weeks after the meter's read and if it's an active leak, we sure as heck don't want to wait two more weeks of a leak. So they get a door hanger, and then they also got a courtesy letter. If

> we don't get a response and it's a double high, I get letters from the billing department. I try and call them, but nobody has their current phone numbers in because everybody has got rid of their home numbers and they all have cell phones now. So I sent her a letter. And they went from 5 to 26 HCF.

The customers in this example went from their regular $60 bill to a $500 bill in a month. Most outdoor leaks are invisible to customers because water flows underground without an above-ground trace. The most common indoor leak is a "silent" toilet leak that can cost customers hundreds of dollars a month without their knowledge through a poorly fitting flapper inside the tank. One of the areas of work David realized through information seeking that they could change was to greatly reduce the time between catching and resolving a leak with interval data. He saw potential for savings of both water and money through applications of interval data.

As people at Suntown participated in the information seeking activities, their sense of what they could do with AMI interval data expanded to other areas beyond metering. Camilla, a water resource specialist, shared her developing sense of the technology during this period:

> It's hard for me to explain because my understanding of it is still not a 100%. But my sense is we will be able to get a better idea our system overall. Part of the issue is when our data is taken because everything on the consumption side is manual. But everything on the production side is we have an automated SCADA system. So we have really, really detailed data in terms of pressure zones and reservoir levels and things like that related to production. But we can't get data on our consumption side unless we go physically look at every single meter. So we'll be able to have this detailed information from SCADA of what's going into a pressure zone, and then with AMI, we'll be able to match that and have detailed information that was taken the same day that will say this is how much water was used in a pressure zone on the same 24-hour period. Whereas right now the only resolution we have is monthly data. And that's another problem with the water loss issue is we'll have huge swings month to month on our water loss because the data doesn't line up correctly because we just don't have matching data resolutions.

Camilla was responsible for tracking internal water loss, but her work was hampered by having to work with data at different resolutions. To track water loss, an analyst like Camilla had to compare the volume of production with the volume of consumption on a given day. With only one datapoint a month it was impossible to accurately measure water loss within the system from internal underground leaks. Some months when she ran the data it looked like the City had *produced* more water than it sold, which was impossible. Camilla was still learning about AMI, but her sense from her participation in the AMI group was that she could apply the technology to her current work to achieve much greater accuracy.

In addition to information seeking, the experience of the intermediate organizational action within the organization also shaped the expanded prediction. David summed up some of the lessons learned from the meter replacement project in the decade before turning his attention to the AMI project.

> For our small meter replacement program it was very successful. Very successful. You'd really have to be nitpicking if you wanted to say ooh you didn't get everything done because usually with projects you can't get everything you want done. But we did a pretty thorough job and there were very few complaints.

David's emphasis that the project received few complaints was an important part of his assessment. Because the meter replacement project temporarily disrupted water service to every single home in the service area, his success in pulling off the project meant that he organized clear communication to almost 30,000 account holders during the time of service in addition to managing a complicated data integration process without affecting the accuracy or timing of water billing. Another important anticipatory facet of the project was that David made decisions that incorporated early information at his disposal about AMI. He selected mechanical meters that had the added feature of being able to hook up to a digital endpoint through a cable attached to the meter body. This meant that David installed a new meter infrastructure that could support AMI in the future, were the utility to adopt the technology in the 20 years before the meters would need to be replaced again.

One thing that David learned was that it was important to contract out the installation work. He had seen how long it took to accomplish the meter replacement with City staff, and he understood now that hiring outside contractors for such a big project would make it possible to progress quickly while his metering and distribution staff were able to continue with their core work responsibilities. He felt this option was available in Suntown, and compared installation work experiences with his colleagues in a much larger city in the region that had to do all of their work in house “because the unions down there are so strong.” Suntown’s staff were also in a union, but they did not organize to demand that installation projects be done in house.

A second learning that David identified from the meter replacement program was the experience of how complex the data integration management was. The data management work of replacing meters was sensitive to error, and he felt that their success in tracking the new meter information in the billing system boded well for the data integration needs that would accompany an AMI transition. He explained:

> In some ways the meter replacement process was very similar to what we’ll do with AMI because you have to exchange all the new meter information in the billing system. And that takes some thought and care and processing and coordination. But I would say our program was pretty successful.

David was satisfied that he did not lose meters in the billing system or misidentify meter bodies with customer accounts. There was potential for many kinds of data integration mishaps, but his careful management of the process resulted in a smooth, almost unnoticeable meter exchange for customers. He applied these lessons to his predictions for the future AMI project. Furthermore, by working alongside contractors, he found that his staff could learn about the new infrastructure from the contractors and be confident in the maintenance work ahead:

> In regards to the way we approached it. I think we could do the same with AMI. I'm not necessarily banking on our success replacing small meters the way we did that we could necessarily replicate that in AMI, because of the number of things that we have to do [is greater with AMI]. Augmenting our support will be necessary. Hiring some installers or something, and having our city staff assist the project. That way we gain the institutional knowledge, and we can understand the way the system was designed and installed. Having that adoption there will be really important, so I don't want to lose that. I want the staff own it more.

David emphasized the added complexity of AMI compared to meter replacement. Building from his experience with the meter replacement he extended his prediction to consider the long-term maintenance of a new technology system. He was thoughtful about how meter replacement required less in the way of gaining new understanding about "the way the system was designed and installed," and predicted that he needed staff to be more closely involved so that they could manage the system long after the contractors finished installation.

Thus, predictions at the end of the second cycle were more expansive than Suntown people's initial prediction. Their sense of the application of the technology and the data it produced extended beyond metering. They saw applications for new approaches to leak detection and customer interaction, but also for water loss analysis and distribution management. The AMI group began to extend their horizon of application to a slower and longer process that would build in staff ownership. David wanted to balance the speed of hiring an outside contractor with allowing for City staff to learn about and take ownership of the project early on and during its implementation. Their sense of organizational change was still unclear, but they had a sense that organizational change would be advantageous. They developed their understanding and predictions for organizational change in the next sequence.

Sequence 3: Refinement. During the refinement sequence, people turned to matters of organization. After expanding their predictions of AMI to encompass a wider scope of technologies and their applications, many had questions about what would be a better way to communicate about and use AMI data in the agency. Through a sequence of information seeking and organizational action, people refined their predictions of AMI to apply more specifically to their own way of working and structuring the organization.

From Expanded Prediction to Action. Peggy's team started from a prediction that AMI would require broad organizational involvement and openness to the possibility of organizational change. In their information seeking efforts, people wanted information about how other agencies had restructured, hired new staff, and updated job descriptions to best adapt to and support the transition to AMI. Peggy felt her ad hoc workgroup was too small and homogenous in their approach the technology. To go bigger, she needed a bigger base of stakeholders and participants in the change process. Thus, as an organizational action, they recruited participants into the project group from other departments of the agency and the water division. To do this, they made presentations at other workgroups' meetings and organized broad stakeholder brainstorming sessions.

Peggy and David were not satisfied with the information they had gathered thus far. They wanted to dig deeper and get the organizational background on agencies' transition to AMI. David asked Peggy during a meeting, "How should we create new programs with AMI and make sure we set ourselves up for success?" To answer this, they initiated a new means of seeking information through site visits and more targeted interviews with other agencies. Site visits were difficult to organize and pull off when Peggy and her team were busy with their primary work of managing the work of distribution, conservation, and metering, but they still managed to organize several site visits in the region to cities that had already implemented AMI technologies. They reached out to other water utilities both through SURF and through their own contacts. David described shifting from looking at the technologies to the organizational structures around them:

> We used the tech scan to focus on who was doing what with AMI. Now we want to make sure that those agencies that were identified were in some ways compatible or comparable to us. Getting their organizational charts and really focusing on the water resources department of what they do would be helpful, because what we're looking at is how our group is currently structured, how do we want to structure in the future.

David pressed his contacts to send him organizational charts and job descriptions if they were not publicly available online. He wanted to know what bigger and better resourced agencies had experienced to learn about what additional departments and workgroups they developed or what types of changes they made with the transition to AMI:

> [Peggy] and I several years ago went and observed [New Westland] and they were doing a full-scale AMI deployment. We could already see from talking to the project manager that there were some gaps in how they were going to be able to adopt the AMI because they brought it on board more as a project, and not like a program, so we're looking more to make it more like a program. You know, there's also some operational benefits that Peggy's identifying in software where we would be able to be able to communicate better with the public regarding things like water outage or something like that.

They recruited colleagues to accompany them on site visits to observe AMI technology in use and ask managers and their staff questions about their experiences with the transition. In an AMI planning meeting, several members of the customer service workgroup shared their thoughts on site visits:

> David: One of the things we're talking about is another round of field trips, this time to [Desertville] and some other agencies that are similar to ours.
>
> Peggy: Yeah, I want to see the billing system, and see some of the other fixed [radio] networks. Like [New Westland] had a [Acme]'s fixed network that didn't work so now they're with some other firm.

George: We can learn a lot from agencies where it didn’t work.

David: Go in there, interview staff, see the environment they’re in.

Juliette: And they’ve all had things for years. I think 2014 and 2015 are the years they had implementation. There are so many combinations out there.

The group in this meeting used what they knew about the different combinations of AMI technologies that others adopted to ask questions about organization. Peggy’s comment emphasized seeing the new software in an existing billing system, while George reminded the group that agencies that had problems implementing and using the systems were just as valuable as sites where the transition went smoothly. David wanted to see the operation in person himself.

A final area of information seeking that the group deployed was to direct their consultants to do another round of outreach to organizations. In the first round, consultants produced both a business case and a technology scan. The technology scan had been very useful to the group in the prior expansion sequence, but the business case did not give them the organizational scope that they now realized they needed. Instead, the framing for the business case was a limited assessment of how AMI would affect operations, focused on ascertaining the potential financial and organizational benefits of transitions from a manual metering system to AMI. The prelude to the report done by Rogers Engineering read:

> The City of [Suntown] engaged [Rogers Engineering] to provide a comprehensive and unbiased analysis of the costs, benefits and resources associated with transitioning from the existing manual water meter reading system to a new advanced metering infrastructure (AMI) system.

Rogers conducted a basic assessment of existing meter stock, service orders, and the meter-to-cash workflow. They reported that there was a strong case for transitioning to AMI for the

City, and the key benefits they listed were the ability to track internal water loss, enhance customer service, reduce the need for re-reads, and enhance the technical skills of their metering and billing staff. After a few pages summarizing the benefits to the city, the business case devoted the bulk of the report to an explanation of how AMI technologies worked and what benefits they offered. Peggy, already having done her own research on AMI, was unimpressed with the consultants' report:

> [The AMI business case] was kind of a painful process for us. The consultants .. talk about over promise and underdeliver! First of all they were asking *us* to provide *them* information on potential benefits, rather than the other way around. In the end I think some of the assumptions they put into that were a little bit on the generous side. It's still a useful document in that it does contain some of the anticipated benefits. That can give you a sense of well OK these are benefits but they're also the types of things that you can't get the benefit from them unless you've got a person to help take it to the finish line. Sure AMI can help a lot of things, but it's not magic. You still need to follow up and take the data and do something with it.

This comment from an interview shows both that Peggy believed the consultants were overly optimistic in their assessment of AMI at Suntown, and she was disappointed that there was not more of an emphasis on the organizational side of technological change. From the last sequence she had come to understand that an AMI system would produce a great deal of data, but wondered what use it was to her if the organization was not prepared to "do something" with it. Furthermore, the business case only reviewed one firm's fixed network solution and one firm's meters. There was no assessment of how agencies adapted to the distinct offerings and limitations of each type of technology. David shared Peggy's sense of skepticism in a meeting about the business case:

> So you get all of this data, and you quickly want to jump to what can you do with the data. There's lots of things being pitched about water loss for example. Now you can get all of the information about water going into the system in such faster time periods, but there's still a whole lot of development that has to be done before you can really feel confident that it can be that simple. For example, a water system is all of these different pressure zones [shows diagram of city water pressure zones]—we

> don't even have meters on all of these connections from one zone to another, which gets in the way of water loss assessments.

David pointed out in this comment that the water system did not have the necessary physical components to perform the water loss assessment described in the report. Unsatisfied with the business case, Peggy and David went back to SURF to request an expanded scope of research. They hired a new consultant through the network to produce a "utility survey" of comparable utilities. The term "comparable" was important to David. At Suntown the human resources office had a set of comparable cities they used to set salaries. David wanted to find the best organizational structure for AMI. He felt that Suntown needed to be compared to more advanced water systems than those included on the Human Resource Division's standard comparison list, because "Suntown's water system is just about as complicated as you can get." He elaborated:

> Peggy used the tech scan to focus us on who's doing what with AMI. Now we want to make sure that those agencies that were identified were in some ways much more compatible or comparable to us than what we have from HR… we want to get organizational charts, job descriptions, and really focus on the water resources department of what they do because we're looking at how is our group currently structured, how do we want to structure in the future—how do we create new programs, and make sure we set ourselves up for success.

David's comments made it clear that his focus has turned from technology to organizing. He had developed a sense that AMI could be useful outside of just metering, and he did not assume that the organizational status quo was the best option for the future of the agency. His information seeking was driven by the goal of understanding what programs and workgroups would be best suited to enable his staff to benefit from the new technology. He considered his best resource to be other organizations who had gone through the change process already. He expressed that organizational charts and job descriptions were most useful to him because in the future if he wanted to propose changes to the Human Resources Department he would need examples of similar organizational structures to support him in that effort. Combined with the focus of information seeking on organizational structure was organizational action to cast a wider net for participants in the AMI project.

Organizational action took the form of participant recruitment for the AMI workgroup and its brainstorming sessions. David and George shared Peggy's sense that more people in the division needed to understand and use AMI than just the metering group. In this quote from a customer service workgroup meeting, George strategized with Peggy about how to build buy-in for AMI more broadly across the division:

> Peggy: The outreach strategy we were talking about was doing the water treasury finance and then maybe doing a core user group: Parks and Rec, the golf course, other large water users.
>
> George: I see this dominating the Water Finance agenda. It's good Renee is in control of that agenda because we really want to take control. This is going to be a dominant part of that meeting for that group.
>
> Peggy: We also wanted your input in engaging upper management, [lists names of heads of other departments]. What do we feel like is the right level of engagement? Timing.. format.. cause if we don't get Jim [the finance director] on board, it doesn't matter if we get the new billing supervisor engaged in the process. We need him. We should do some brainstorming activities with them about AMI.
>
> George: I love it. If nothing else, this is engagement. They should feel like they have some ownership.

George pushed Peggy to bring others into the process so that they could participate and feel ownership. Importantly, the group of people this group brainstormed in this meeting included not only departments who would use the data in their day-to-day work, but also departments who were themselves high water users. Peggy saw an opportunity for both broader City support for the project as well as for actual water conservation if groups like Parks and Rec or the golf course were to use AMI data to regulate their own water consumption. Throughout the early phases of researching and promoting AMI in the division, George supported Peggy to aggressively build engagement for the project widely. Some of the ideas that came out of this brainstorming session were for individual “mind map” interviews with potential stakeholders, to visit other departmental meetings and present on AMI, and to hold a large meeting to share insights and solicit feedback from department supervisors whose participation the group felt was important.

The two departments that the core group felt were most important to bring on board were Billing and Information Technology (IT). IT was important because the group expected to need a great deal of technical support during selection, implementation, and use of AMI. Billing was important because successful AMI transitions have included billing staff at the heart of the change process. When billing staff understood and were comfortable with the new software and in interpreting interval data, agencies reported that this greatly improved efficiency in customer interactions. Phone calls with customers were one of the most time-intensive areas of work for many staff, and any opportunity to reduce call length and volume was desirable for managers. At Suntown, however, the billing group had not shown much interest in AMI. To make matters more difficult, the billing group was going through staffing transitions and Ramona, the new supervisor, was struggling to get up to speed in her new position. In the interaction below, Manuel and Peggy chatted before a meeting about how to get Ramona up to speed on the project. The consultant usually facilitated the weekly status meetings, but he had not yet arrived and Manual and Peggy had a few minutes for a casual conversation about how detached and sometimes disorganized the billing department seemed to them. Manuel had noticed that there had been a lot of turnover in the department, and pointed to this as an explanation for why he had not had much success in getting Ramona to attend meetings or software demonstrations:

Manuel: There's just a personnel vacuum over there [in billing].

Peggy: I think we need to work with Romona one on one and mentor her. I didn't want to get too involved, but I feel like Ramona could be more successful if she had someone who understood the billing software better to help her field her questions, give advice, and be someone she could turn to, so I'll do that.

Manuel: Cool.

Peggy: I can be your go between if you feel like you're not getting what you need from her. And I'll encourage getting her staff more involved.

While Peggy had delegated the outreach to billing to Manuel, in this conversation she committed to get personally involved to help bring Ramona along. The City was organized with clear hierarchies within departments, and both Manuel and Peggy were aware that if Ramona as department supervisor did not signal to her staff that AMI was important, the project would suffer from the lack of involvement from billing staff overall.

To reach out to the IT group, George and Peggy went to several IT meetings to give presentations about AMI and ask supervisors to include supporting AMI in their workplan going forward. At one meeting, Peggy met with a few IT staff to introduce AMI to them for the first time. For most of the meeting, Peggy explained what AMI was and what they had learned from their pilot programs. IT staff asked follow up questions, but it was not until Peggy shared a template for a Request for Proposals (RFP) that the IT director showed an interest in participating in the process in some way:

Peggy: So another thing as the guys would be interested to know, we were part of this [Network for Efficient Water Consumption]. They gave us a template for an AMI RFP. So if you're interested in, you know, reviewing some of the software stuff, or firmware…

Amira: You haven't done any changes to the template at this point?

Peggy: Yes, exactly. We're just in that stage of starting to look at it, use our experience we're gaining to understand what we want to change.

Amira: We should definitely look at it for you and make sure that it has all the technical specifications we require. You need a point person for technical support on this.

Amira's offer to review the RFP was an important first step because it brought the IT group into the AMI process. She was interested in the RFP template specifically, because it was through the RFP that the City would eventually procure an AMI system. If the IT group could intervene early on technical specifications, it could save them a lot of work later trying to integrate the new technologies into their existing systems.

The IT group was in a difficult position within the organization. On one hand they were often frustrated when departments of the city went through a major technological change process without working with IT staff from the beginning, but on the other hand they did not have enough staff to both offer on-call help desk support and engage in strategic planning and implementation projects. As Amira explained in an interview:

> When I started here, this city was not tech-forward at all… And suddenly they see all these things that need to be done, and they want that to be a priority for IT. They want all their new systems and all their things that they want to implement done. We're not sitting around here waiting for them to do that, but that kind of can be the expectation. So on the one hand, it's nice that somebody wants to do all that stuff, that we're no longer trying to work with people who are resistant or not on board with things, but it can also create this sense issue where they start thinking that we're not being responsive enough. We're already busy, and we just don't have enough staff.

While Amira was supportive of the City becoming more "tech-forward," she emphasized the difficulty of meeting the City's needs given her current resources. The strain on the IT group was important for the AMI project because members of the AMI group expected to need a great deal of support from IT in the year ahead. Amira was frustrated with the way that departments throughout the City initiated technology projects and then expected full service support from her group. She elaborated further:

> It‘s our observation, from a management perspective in IT, that how the city is often run causes problems. Each department is very siloed, but they work with us to some extent because they have to. They use our resources, but sometimes they try to ice us out or go ahead and contract with somebody [for a technology] that‘s not really secure, or not recommended. Even worse, it‘s something we already have and do. But some other product has a slight variation to it, and these groups [in the City] are very insistent that they need that product specifically. So we have to work with them in whatever manner we can. Maybe we don‘t like what they‘re doing, and we don‘t recommend it, but then ultimately, we end up having to support it in the end.

In this quote, Amira’s frustration with how her colleagues adopt new technologies comes through clearly. She felt that her expertise and opinions were not valued when departments bought and began implementing new technologies against the best interests of the City overall. Sometimes the City already owned a product that could accomplish what a smaller group wanted, but often a group had become enamored of a specific product and were insistent on its adoption. Amira was responsible in the end for making everything work.

Through Peggy and George’s outreach to the IT group, they were able to develop a way to involve IT with more advanced planning. Amira proposed using a newly-designed IT intake process. Her hope was that departments in the City would use her intake process to propose new technologies to the group and work together to establish a timeline. Amira decided that the AMI project would be the first use of the IT intake process. At an IT steering committee meeting, Amira invited George and Peggy to present AMI to the group for approval. Amira started the meeting explaining that normally they would go about assessing a new project in a different order on a longer timeline, but she was sensitive to the AMI group’s timeline to meet a grant deadline:

> There is one item on the agenda today, which is automated metering. This project is why we hustled to get the intake form done at the last meeting. It’s a foray into our

> new mechanism, which is this intake form. We're doing this a little out of order. In the future a department would have a pre-meeting with IT, we'd do research on the proposal and then bring it to the executive committee. The reason why this is out of order is because there is a deadline related to a grant opportunity. Our job is to understand what the project is from IT perspective, so this is staffing levels, time commitment, statement of work for IT request. We don't need to discuss the entirety of project, but rather what do they need from IT. What kind of help from IT around selecting a vendor, etc. We need to make a recommendation about whether we should move forward with the project and when it should be scheduled.

In this meeting the group asked many questions and finally approved AMI and added it to the IT schedule as a priority for support. While some in the group were skeptical of the timing, they were persuaded by both the fact that the project had recently won a $1 million federal grant that had come with its own deadlines, and that unlike other groups in the City, the AMI group had come to them ahead of time rather than once the technologies were already undergoing implementation and running into problems. Both Amira and Peggy were thrilled at the outcome. Amira was enthusiastic about the launch of her IT intake process, and Peggy had more confidence that the project would get adequate support from the IT group. Through their collaboration they produced a new organizational process that, if used by other groups in the city, they hoped would better structure the City to manage technological change going forward.

The actions taken by the AMI group were fruitful. Through information seeking input from other organizations, Suntown's people brought back new information about how other cities had adapted their staffing and workflow structures to an AMI system. Through engaging more directly with other departments in the City, they had a better sense of how they could progress forward with a broader group of stakeholders. Each of these areas of insight contribute shaping a more refined prediction of how AMI would work at the City.

From Action to Refined Prediction. George's role as water resources manager at the City and in the AMI project was often to push his staff to think bigger and more creatively about their work and how the organization could change in the near and more distant future. He often voiced opinions in AMI meetings that brought the group back to the bigger picture goals of the project. He summarized their position in an interview:

> Right now we're piloting several different technologies. And I hope by this time next year we will have selected a technology to move forward with, but that is going to change our practices significantly, so we're trying to project out what that's gonna look like.

What that projection looked like during the refinement sequence of activity was more focused on organizational alignment to the use of the AMI system. One positive effect of the group's activity in bringing more senior members of the City into the AMI process was to increase the status of both the project and the group's predictions of change. More than just a metering project, AMI had become part of the division's goals for improving the image of the City for the customers overall. In the following example from a customer service meeting, George worked with the AMI group to brainstorm future uses of the technology in line with his goals for public relations:

Peggy:	I'm going to use the whiteboard. OK. so, project purpose—why are we doing this project? not what's involved, but why do we think this is a good idea?
Juliette:	Customer service. [Peggy writes each idea up on the whiteboard]
Peggy:	What about customer service?
Juliete:	Better! Transparency!
George:	I would also go to expectations—customers have that expectation of service at this point. In this realm of global connection they expect to have access to this kind of data if they were interested. So the

expectation is that I can turn my coffee maker on with my phone why can't I see my water usage?

David: Embracing technology is a big thing—gas, electricity…

George: Everything is web connected. I can easily turn on my irrigational controller with my phone, so why can't I see how much water I'm using? I would consider those expectations in today's... what do we call it..

David: Information age! This is going to help us refine our customer service goals and expectations in the information age.

George: I believe we'll be able to provide better customer service when they call with a problem.

In this conversation, George and his staff predicted that AMI would help position the city as technologically advanced and participating in the information age. George did not want customers to see their service from the water division as poor in comparison to the more technologically advanced service they received from other utilities or third-party technologies they used for their irrigation systems. In the surrounding region, gas and electric utilities had installed AMI systems in the past decade, and customers were able to access interval data about their gas and electricity usage. Water utilities were alone in continuing to produce a single data point per month about customer usage. George pointed out the example of customer phone calls to the division because often it was only when customers called the city with questions or problems that they interacted with the City about their services. In many ways, customer phone calls to the billing office were the front line of public relations with the City. George wanted these interactions to be useful, efficient, and effective so that customers had a positive view of the City overall.

A facet of the refined prediction was a more specific sense of the roles that would be needed to make the project successful. One area of organization that the AMI group came to predict as key was enhanced IT support. While they had gained approval from the IT department for the project, they had learned from their outreach that dedicated IT support was important. To this end, they predicted needing an additional IT position funded by the Water Division dedicated to the AMI project. This was a novel approach to organizing IT support, as no other departments had IT staff that were funded by a specific department of the city. Camilla explained this aspect of their refined prediction in an interview:

> We just know that we're going to need significant help and this is where things can go wrong. You need an expert. Like [Islington] has an AMI integration expert for three years and they have an IT integration person and those people work together. Maybe we don't need something at that scale, but it's something beyond ¾ of Mitchel's time. It's a much bigger scope than that.

Camilla identified Mitchel in this example because Mitchel was the IT person to whom the metering staff often turned when having technical problems. Mitchel was a knowledgeable and efficient IT expert, but many people in City relied on him. Camilla gauged that even with ¾ of Mitchel's time they would be insufficiently supported. She learned from outreach to another City, Islington, that a dedicated integration expert was another option.

An additional aspect of the refined prediction was a more explicit prediction of how the meter readers' work and job classification would change. While there had been some anxiety among meter readers early on the process about their job security, many of them had come to understand that they would still be employed and useful once AMI was installed. Arnoldo, a long-time meter reader, shared his thoughts while out in the field capturing meter reads manually:

> I welcome AMI, personally. I'm glad that they are moving forward. I think what it's gonna do is just change the way we do things. There's still gonna be work to do.

> Somebody is still going to have to manually shut down water service, and our maintenance guys have their hands full. They struggle just go keep enough people on hand, and they don't have extra people to go out and do services cause that's still a full time job. And they're still gonna want people to manually read the routes from time to time, just so you can get an overall view of what‘s going on on the ground. So I'm thinking for at least the next 10 years or so it‘s probably still gonna be pretty much the same. That's what I'm foreseeing.

Arnoldo's quote demonstrates a measured, long-term view of change with AMI. When Arnoldo and others first heard about AMI and knew little about it, it was easy to get caught up in an expectation of sudden and dramatic change. With time and after sequences of information seeking and organizational action, Arnoldo and his colleagues predicted that the change would take time and would require the expertise and know-how of the meter readers. After all, they were the only ones who knew the city's metering system from the inside out. They knew where every one of the City's 30,000 meters were by memory and understood what kinds of problems came up and how to fix them. A benefit of the refined prediction was that few people at Suntown were anxious about their place at the City once an AMI system was installed. Earlier on in the group's predictions, both meter readers and their supervisors understood that metering work would change, but few had clarity about what that might mean. Peggy developed a sense of how she could reclassify meter readers as "meter technicians," and expand their scope of work to include more technical aspects of the meter system that would benefit from their hands-on expertise:

> I'm excited about in the future that the meter technicians would be able to handle some of these things a little bit more themselves. If just the meter register's scratched, they could take that register off and put a new register on. They can learn the skill set to be able to follow that process all the way from start to finish as far as initiating that as a problem, confirming it's a problem, getting the materials that they need, actually doing the install, and then also bringing the information back into the office and updating it with the software. It's not as simple as like, "Oh, you just grab another register and take the one off and put the other one on." No. There's a little bit more to it and so I would like the metering group to have that skill set to see that all the way through. They should be able to handle some of these things that have more

> immediate consequences and then only hand off things to the operations group for bigger jobs that really you might need heavy equipment or a blowtorch or stuff that you can't just use your regular stuff in the meter tech's toolbox to handle.

Together, Arnoldo and Peggy's thoughts on the meter readers' future was as a measured, long-term change in concert with the adoption of a new technology. Both described a future in which the experience and skills of the meter readers were important assets to the transition to AMI, while at the same time provided a basis upon which meter technicians would be able to expand their job responsibilities and skillsets in an AMI system. The expansive and refined qualities of Suntown's predictions at the end of the introduction period were the result of three sequences of action and prediction. Suntown's experience contrasted sharply with that of Fogtown's introduction, which in comparison was more abrupt, politically troubled, and narrowly focused.

Fogtown's Introduction

Like Suntown, Fogtown encountered a roadblock in the early days of AMI introduction. Their project was hampered by a dysfunctional City Council and senior management's fear of extremist anti-5G activists who had blocked other recent municipal water projects. Unlike Suntown, this roadblock derailed Fogtown's AMI groups' work and curtailed their predictive sequencing. As a consequence, Fogtown's introduction period consisted of only one activity sequence. The early prediction they came to share did not develop and evolve through a sequence of expansion to refinement.

Fogtown's ad hoc AMI workgroup began not with a proto-prediction, but with a reactive organizational action. Later, after a supervisor intervened and called for more reflection and research, people at Fogtown formed predictions and began information seeking for more information. The model of Fogtown's introduction phase is depicted in Figure 3.2:

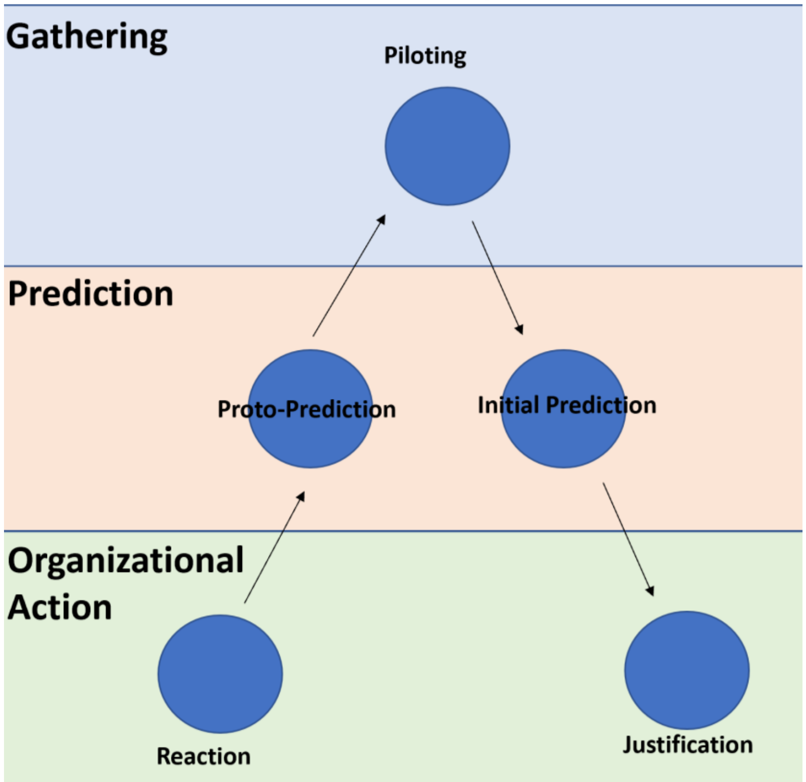


Figure 3.2. Fogtown's Introduction.

Sequence 1: Feasibility. Over the course of the feasibility cycle, people at Fogtown produced predictions about the extent to which AMI technologies were an appropriate and practicable project for their agency. Unlike Suntown, where people developed a proto-prediction of AMI before taking action, Fogtown incorporated AMI endpoint installation into their reactive maintenance status quo. Once people stepped back from the many problems in the meter system they looked towards the future in a different way and went beyond their organizational boundaries to gather new information to inform and shape their predictions about the technology, its temporal horizon, applications, and need for organizational change.

Reactive Organizational Action to Proto-Prediction. When Evan, the customer service manager, and Mick, his meter shop supervisor, learned about AMI from Acme, their AMR vendor, around 2010 they were struggling with their metering system. Evan and Mick were the core members of Fogtown's ad hoc AMI workgroup. Both agencies had ad hoc AMI workgroups which were loose, voluntary groups of 3–6 people at any given time who were interested in AMI and wanted to work towards bringing it to the agency. Ever since Mick had supervised the installation and maintenance of a digital AMR system in the decade before, the meter-to-cash process was plagued with missing data, incorrect reads, and buggy data integration processes. By 2010 both the digital components and the meters themselves were failing at an increasing rate. When meters begin to age, they slow down, under-registering water consumption until they finally fail to register any flow at all. Mick described the state of the system at that time:

> By the time we finished [installing the AMR system] after eight and a half years, we were already having some of them die off. I guess the analogy for us was like painting the Golden Gate Bridge. You start painting at one end and paint till you get to the other side. But by the time you get to the end, you have to start over at the beginning again. You can never sit back and enjoy a fully painted bridge. So, we found ourselves very quickly doing replacements of batteries and having units dying off all the time. So I mean, we went right into kind of permanent emergency maintenance mode.

Acme was a big international firm and Mick had worked with them over the near-decade-long AMR installation period to troubleshoot and repair the digital components and radio network. In 2010, Acme pitched Mick on switching over to a new technology called AMI and told him that AMI endpoints would work over the same radio network Acme had built for Fogtown for the AMR system. Mick was eager for any new approaches to start to stem the tide of failures, and AMI seemed like an easy pivot. He described how he decided to take action with Acme's new product:

> We were already in this maintenance mode with our AMR system, and then by 2010 AMI was out. To me, the transition looked like it would be a natural one to stay and go with Acme on it because when as our MXUs died off we could just replace them with a AMI unit. That's kind of the way I was looking at it.

While Mick's frustration a decade into the process comes through clearly in this quote, it also shows that at the time that he learned about AMI he was optimistic. He assumed it was an easy switch for him that could help him turn a bad situation around. His action was an example of what many at Fogtown often referred to as "backing into" technology. Hunter, a utility account specialist explained:

> Some folks in our org like to call this "backing into [Acme's] AMI system" some years ago. We never fleshed out our system completely but we have been replacing AMR with flexnet [AMI] radios for some years.

This first introduction step for Fogtown was reactive, in part, also because Mick did not approach the technology as any different from his existing system. The move to AMI was identical to his existing work practices and involved a minor subsitution. Mick sourced AMI units from the firm with which they were already contracted and expressed that he would likely have continued until his supervisor intervened and redirected efforts. This first step is depicted in Figure 3.2 as "Reaction" in the overall model of Fogtown's introductory period.

Initiating a new technology in a reactive first organizational action had consequences. A report produced later by consultants summarized the impact of Fogtown's early initiaton activities during an assessment about five years later:

> Currently, the City has a reactive meter maintenance program, replacing meters and radios when failure is discovered. Over the past six years, the City decided to replace these failing meters and AMR radios with AMI-enabled units and has discontinued installing AMR meters. In 2011, the City agreed to purchase and install [Acme]AMI collectors to automate the meter reading process and has been installing AMI radios as old AMR units fail; approximately 4,700 of 27,000 meters (17%) have been upgraded to date, some being entire routes.

> During the upgrade, however, the AMI radios were not installed through the lid, nor were lids replaced with [Radio Frequency] friendly composite material. This, coupled with other factors such as shadowing, interference, and power outages, has caused the [Acme] AMI system to not meet performance expectations (98.5% of meter reporting every 72 hours).

The consultants' assessment shows that the change from AMR to AMI did not resolve Mick's metering problems for two reasons. First, the AMI units communicated over the same faulty radio network as the AMR system. Network outages plagued the service area and many endpoints did not communicate, and after experiencing many unmet promises from Acme, Mick did not have faith that their proposed network solutions would work. Second, the AMI units were not installed properly (lack of power, material interference with the meter box lids, etc.). The failure of the Acme AMI endpoints and network in turn shaped the City's first proto-predictions of AMI.

> So we did that for a little bit. But my boss at the time basically wanted us to step back and see if this is what we should be doing. And I'm glad he did it. But you know, that was probably about, what, 10 years ago, almost, yeah, we still don't have an AMI system…

The pause made up an early "proto-prediction" that AMI was different than AMR and the City should look into whether other options were available to consider.

Proto-Prediction to Information Seeking. After both AMR and AMI units failed on the Acme radio network, both Mick and Evan came away from their first attempts with AMI with the assessment that a radio network was not optimal for their city's hilly coastline. They were weary of the cost and effort of maintaining their own radio network infrastructure (or "backhaul," as it is called in the industry). Mick had struggled for years with a poorly performing radio network, and he was eager to get away from the modality. He and Evan reported in the division's weekly newsletter about their displeasure with the firm managing the radio network:

> Tomorrow, [Evan and Mick] will meet with the IT Director and several staff to review the AMI service agreement with [Acme]. Last Friday, we received a software upgrade quote for a quarter of a million dollars. According to [Acme], this upgrade is the only way to bring our third tower online, and we're wondering why they didn't bother to tell us this before we bought the tower. Actually, this bait 'n switch tactic is old hat for [Acme], so part of tomorrow's discussion will invariably be about where this client-vendor relationship is going and whether we should break it off.

Clearly, Fogtown leaders were displeased with the consequences of their reactive approach and their intention to start looking further afield.

Much of their frustration was with the ongoing failures of the radio network. To use either an AMR or AMI system on a radio network, an agency has to build its own communication network of radio towers, "repeaters" that expand the reach of the towers, and license an FM signal from the Federal Communication Commission. Agencies own the network, but they typically pay an annual fee to a firm to maintain the network infrastructure for them; however, they can also opt for in-house management. Because Fogtown's network was performing poorly for the AMR system, the firm recommended installing another tower at the agency's expense. As summarized in the departmental update, to Evan this was further evidence of a pattern of poor planning and management on the part of the firm. They shared a sense that another type of network could work better. Unlike their counterparts at Suntown, neither of them had many connections in the broader institutional community, but they had heard a few local contacts about a cellular alternative:

> There's a water agency over in in [Desert Valley]. They did an AMI system with the [SharpBeacon] system, and so did the University here. The University replaced all their radio units because they were having problems getting reads up there, but I don't know if you're familiar with the terrain around here, but [the campus] is up on a hill here. There's a lot of trees and just dead zones for radio frequency there. For whatever reason, though, that cellular seems to work much better up there.

They used this information to form a proto-prediction that a cellular network could solve their problems.

At this stage their prediction was a proto-prediction because they had not yet gathered any information beyond what they experienced with their first attempts at swapping AMI units for AMR and what they heard anecdotally from a few contacts. In considering their metering problems, Evan and Mick simply predicted that a cellular network infrastructure could peform more reliably. As Evan explained:

> We liked the idea of a cell network because of topography. We had [Acme's] radio AMI deployed and we were just going through so many problems. With [Acme] it felt like a sales pitch the entire time. They promised "its gonna work it's fine it's fine," and for us there's a lot of responsibility we need to take because honestly we went about it all wrong. We just plugged in the tower and put in a bunch of radios. We just didn't know what we were doing and how to really verify that the system was going to be the right system.

Evan reflected that their early steps were not based in assessment or reflection, and thus were not very well executed. The Fogtown group looked towards a pilot program with the hope that a different kind of system would improve the meter network problems.

To test their prediction and learn more about reading meters with the cellular network option, Fogtown launched an information seeking effort in the form of a small pilot of a few hundred AMI meters. They worked with a firm "SharpBeacon." SharpBeacon built AMI systems that operated exclusively on existing cellular networks. If the cellular network performed well in the pilot, Evan and Mick hoped that it could help them extract the agency from their radio network. Hunter, a utility account specialist and early supporter of AMI, described his hopes for the cell network pilot:

> [With a cell network] we don't have to own the backhaul. I think the main point is in looking at [Acme's] network they were telling us to get up to the 98.5% read success rate that is industry standard that we would have to add at least one more tower and a number of other repeaters to fill in our system. And we just didn't like the idea of owning the backhaul and dealing with that all of that stuff. There is a potential long term disadvantage because we are beholden to the carriers. But the advantage on the flipside to that is the customer base for a cell system is not just the AMI provider, but

> happens to be every single person that has as cell phone, so you have a lot more reliability leveraged because they have such a broad customer base. If the fixed [radio] system goes down and we need tech support, we're just one customer instead of 20,000 or two million. There's a lot of incentive to fix it!

The small, ad hoc group acquired 400 cellular endpoints and installed them on many of the city's irrigation accounts. The information they gleaned from the pilot next shaped their predictions of how Fogtown might benefit from and use AMI technology.

From Information Seeking to Initial Prediction. Evan, Mick, and Hunter were enthusiastic about the pilot. Reads came back reliably from the field on demand with only "a touch of a button." For Mick, the question was settled. He was ready to move ahead with SharpBeacon's product immediately:

> So with AMI [on a cellular network] basically, you put it in the ground and turn it on. So we did a pilot with the [AMI cellular] product… And once we were able to pilot it and recognize that it was a good product, then we started moving forward with trying to get a new system in here. I wouldn't do it the same way like we did with Acme again, just because especially with AMI you'd never recognize the benefits of it, waiting eight years to get it all installed if we did it in house again.

The experience with the pilot helped shape Mick's sense that a cellular-based system would resolve many of his technology problems, but they needed to hire contractors to install it. His quote shows how he predicted that they could move to get the new system installed and reap the benefits more quickly. Importantly, this meant that Mick and his colleagues moved past a reactive approach and shifted into a cycle of prediction, information seeking, and action. In their initial prediction after the pilot, they predicted that the SharpBeacon product would more effectively automate the meter system. Hunter summarized their impressions of the firm:

> Another thing is that we really liked the service that we've gotten with SharpBeacon. We like working with them. They are very responsive and through these pilot projects established a really strong relationship.

Hunter supported the decision to try and move through the City's official channels to get the system installed.

The group's predictive horizon was short, because they expected that the benefits of a programmatic replacement of the metering technology could be realized quickly if they could secure funding and find a third-party installer. Their application was also limited, as they only talked about and worked with AMI as a metering automation technology without a sense of use in other areas of work in the water division. Finally, their only sense of organizational change was that they should outsource the installation instead of trying to pull it off in house. The AMI group predicted that the technology needed to be installed in a shorter period of time (i.e., less than the eight-and-a-half years they devoted to the AMR installation) to be successful.

From Prediction to Organizational Action and Its Consequences. The experience with the pilot helped others in the meter shop understand and appreciate what AMI could do. The first organizational action in the first cycle was "justification," in which they presented a feasibility study and business case to decision makers at the City. Evan recruited a colleague from the conservation department and a utility account specialist and got funds to contract a consultant to write a business case. They were excited by the business case produced by the consultant and felt it strongly supported an immediate move to AMI.

The city was due for a system-wide meter replacement, and Evan and his colleagues believed the timing could not be better. They put out a Request for Proposals (RFP), selected a firm, and directed the consultant team to study the City's problems and assess whether and how they should implement AMI. A list of the City's problems and their intent, as summarized by the consultants, was to address:

> …critical challenges faced by the City [including]: stuck, aging and under-reporting meters; failing drive-by, or AMR, radios; obtaining 100% of each month's billing reads; the inability to provide customers with detailed usage and leak detection information; and the inefficient use of staff time in obtaining reads and maintaining an aging system.

Fogtown's customer service team had a clear set of problems that needed solutions, and the AMI workgroup was motivated by their prediction that the SharpBeacon technology could be the answer. The agency's problems ranged from failing and poorly performing technologies like meters and radio transmitters to the more social problem of wasted time. As an explanation for the agency's persistent frustrations, the consultants emphasized the reactive nature of the City's metering program in framing the business case. They summarized,

> [t]his report identifies the most appropriate technologies, determines anticipated costs, and calculates the added benefits of a *proactive*, AMI-enabled meter replacement program compared with the current meter-failure driven, *reactive* replacement approach…. Currently, the City has a reactive meter maintenance program, replacing meters and radios when failure is discovered. Over the past six years, the City decided to replace these failing meters and AMR radios with AMI-enabled units and has discontinued installing AMR meters. Based on the age of current meters, it is expected that a significant number of radio batteries (representing approximately 40% of the customer base) will fail in the next few years. These failing meters will need to be addressed, regardless of AMI program decisions. *[emphasis added]*

The consultants described a bad situation that was on track to get worse. The AMI group was optimistic about the impact that the business case would have and took it to managers as part of a proposal for funding a multi-million dollar system-wide replacement. To their surprise and dismay upon presenting the business case, however, they were rejected. Evan explained,

> I went to an early stage gate meeting with our business case. It was the kind of meeting where you take your analysis to the board and you present on it, and hopefully the board says, "We understand it's feasible. Move on to the next stage." So we did that with the business case, and the board basically said, "We understand this project and we understand we should do it for all the right reasons, but we're not going to do it. And we're not going to do it because it's not the right time to do it in the community." And this was when 5G acquisition was kind of full swing.

Evan was taken aback that his managers were unwilling to move forward for fear of protest by a fringe group of activists. The same group of activists had pressured the City Council to derail a $10 million desalination water supply project several years before, and the impact of the political failure still echoed throughout the division.

Morale about new projects was at a historic low which impacted the AMI proposal, as Lucille, the acting Water Division Manager explained:

> Well, AMI has a political shadow. And I worked on the Desal Project which has a similar kind of shadow where you have to be really careful about how you talk about it and when you talk about it and who you talk about it with… We can't have the anti-5G people with tinfoil hats showing up like they did with Desal.

Lucille and other managers were still spooked by the desalination project's failure. They did not have the confidence to move forward with a project that might stoke the fears of the anti-5G activists. For Evan, working with consultants to produce the business case for AMI was an important first step in a bigger AMI project that he intended to lead as the customer service manager with his small team. His team was united in the opinion that the business case showed both a clear and urgent need to transition to AMI without delay, but also that it would save the division a great deal of money to act decisively. Evan often returned to one infographic in particular that "looks like the Eastern Sierras" that he thought decisively proved his point on the need for investment. See Figure 3.3:

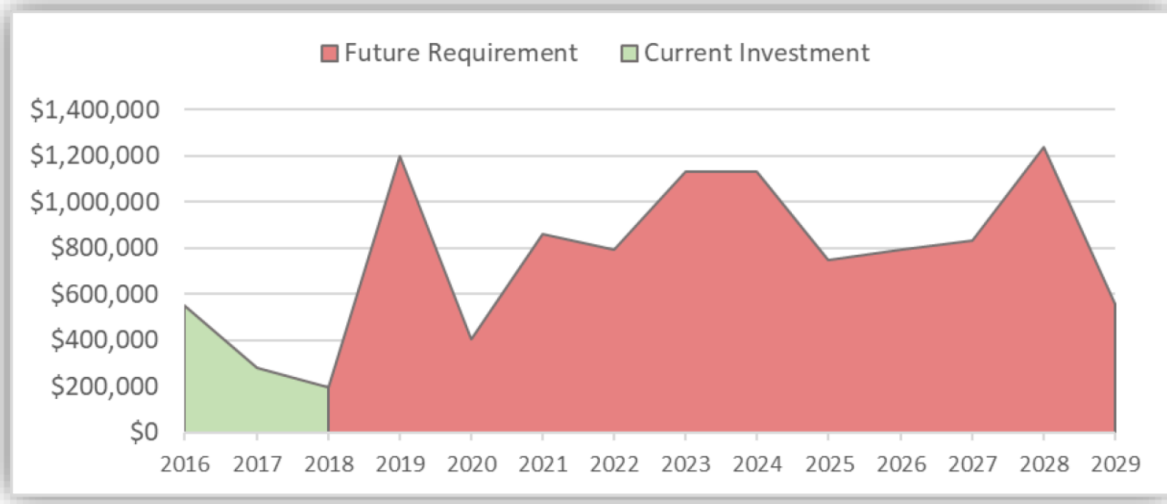


Figure 3.3. Future Investment Needed to Maintain Existing Meter and Radio Equipment.

The rejection was a blow to morale for the project, and the AMI group interpreted the response to their business case as part of a larger dismissal of the problems of metering. Some began to lose motivation to make infrastructure improvements. Evan summarized the mood of the group at that time:

> And that was a really bitter, bitter point in time for the team because we had worked really hard on the business case and we felt like if we had the support of the entire division, if the division had the will to move forward on this project and make plans to address the potential for community oppositions, and invest in a robust communications plan around it, then we could just stay the course. But the division said, essentially, "We're not willing to do all of that. It's just not the right time." And so, "We're very sorry." And so we're sitting there going, "Okay, great." We thought we had this thing ready to go and the next step was to put the RFP together. And in the meantime, the whole system's dying. Things are failing every single day and we have to do something about that, right? We have to replace the equipment because we need to get monthly reads. So, as a group, we sort of sat back and said, "Well, what are we going to do?" And it became very—and I was very fatalistic, or something. We all sort of were like, "Fuck it." I mean, we don't have the support of the division, so I guess we're just going to replace ad hoc. And if shit really falls apart, then the division will have to live with their decision.

A consequence of the political roadblock was a pause in all AMI activity. Decision makers' jitters about 5G technology blocked not only the team's ability to move forward with adopting AMI, but also to address the failing meter system that was similarly in need of replacement. The two projects were linked. They became frustrated and demoralized and as a consequence were unable to identify alternative paths forward for the project. Without additional cycles through information seeking, prediction, and organizational action, Fogtown's prediction for AMI technology remained largely intact. Instead of developing a broader understanding of what the technology was capable of or how the organization might implement it to achieve digital transformation, they stalled out at a prediction about a limited AMI technology with application for metering and the meter-to-cash workflow.

One explanation for the roadblock was that Fogtown metering was a lower status category of work in comparison to distribution, supply, or engineering work. Metering work required fewer certifications and many perceived it to be an entry level occupation. Accordingly, the narrow association between AMI and metering meant that the project as a whole was lower status than that enjoyed by Suntown. Hunter, a utility account specialist who worked with Evan to try and push AMI forward, explained:

> Metering has always been the step child of the water division. The division manager has *never* been to the meter shop. We are an afterthought even though we're where the money comes from. In some ways we have enjoyed the anonymity that came with that, but now when we have a problem we have to wave our hands around to get their attention. For meter replacement, we've always been saying that this is infrastructure. But meters are not considered an asset. They have always been considered ONM-operations and maintenance.

As Hunter described, there was a significant cultural hurdle the AMI team needed to overcome. Metering had historically been classified by the division as an operations and maintenance issue, rather than as an asset that required the kind of funds, planning, and attention received by capital improvement projects. Evan and his team felt that AMI was a big enough project that it should be treated as a major investment into an existing asset. Unfortunately for Evan, management did not see it in the same way. As one senior manager explained, “AMI doesn’t walk and talk like a CIP [capital improvement project]. There aren’t a lot of bulldozers and concrete involved.” Evan characterized the differences as part of the challenge between “upstream” and “downstream” culture in the division:

> We felt miffed that the division didn’t want to do [the meter replacement project]. It fed back into our overall feeling that the division doesn’t have a lot of respect, or doesn’t think too much about the meters and what I call “downstream operations.” In my world the point of business is the meter to the customer. Everything upstream of that—the lateral to the main to the transmission main and all the way back upstream to the watershed—the division has a huge focus on everything upstream. It’s a historic problem. It’s deep. It’s cultural. I don’t know if it’s different with other utilities—maybe they focus more on meters and customers. It seems to me that up until now meters have always just been a piece of ONM equipment—you put it in the ground, check on it, and replace it when it fails.

The division’s rejection of the project curtailed any further investigation into the technology by Evan and his team.

Without new information coming in, their stakeholders’ predictions remained unchanged. Lucille described both her assessment and pessimism about the promises of AMI and her belief in its limited to application to metering:

> Well, for me, the goal is to get—well, a goal would be to get 100% accurate readings across the board, right? And have people paying for their water… I don’t see the water savings in AMI. I attach AMI to ideas about water savings and customer engagement, and meter replacement with accurate meter reading. And I do feel, based on what we talked about earlier, this is a meter reading effort.

Interestingly in this example, Lucille identified the difference between meter replacement and AMI, in that replacing meters would improve more accurate volumetric measurement, and AMI was thought to improve water savings and customer engagement. Lucille, however, did not believe the idea of water savings promised with AMI was real or even necessary.

An important consequence of Fogtown's curtailment to their experience of the introduction phase was that their predictions did not expand or become more enriched over time. Without further cycles of action, Fogtown's predictions were comparatively stunted at this point. Hunter summarized his frustration with the City's lack of perspective:

> Here in [Fogtown] there has been zero thinking about the change that needs to happen in advance of AMI. I've been blowing the horn about it for years but not getting any traction. We need to retool people. We need to think about it now!

Hunter's comment is useful because it reveals that while some individuals involved with the AMI project were inclined to learn more about how the organization could prepare for AMI and coordinate in advance, the political block on the project made advanced predictive activity difficult. Fogtown's AMI team called the project the "Meter Replacement Project." By encompassing AMI within the meter replacement, other people in the organization understood the project as limited to metering. Fogtown's experience contrasted in many ways from Suntown's introduction period, which was characterized by multiple cycles of introduction activities that enriched and expanded the predictions shared by the Suntown AMI team.

Conclusion

In this chapter I showed how people at two water agencies first initiated the idea of a new technological system to their organizations. The trajectories that each group took through the introduction period before project approval differed in several ways. Suntown progressed through several sequences of organizational action, information seeking, and prediction, such that their shared predictions became more expansive and refined over time. Their extensive networks with other agencies and technology consultants helped produce predictions of AMI that extended into areas of water management work beyond only metering and billing. People at Suntown had a long-term vision of technological change that included a broad and diverse group of stakeholders. Suntown’s trajectory increased the status of the project to be one in line with the organization’s goals for increased transparency and engagement with customers in the service area. In contrast, Fogtown’s introduction to AMI was limited and hampered by associations with low-status operations and maintenance within the metering system alone. Fogtown, struggling with a failing digital metering system, suffered a demoralizing rejection of the project by superiors. The block on the project curtailed any further information seeking and organizational action, and as a consequence the shared predictions of Fogtown’s AMI group did not evolve.

The sequences of prediction and action were important at both agencies because they shaped the initial conditions under which the projects were eventually approved. At Suntown, the AMI group presented the case for AMI to both the Water Commission and City Council and gained provisional approval for their proposed budget. The project had broad buy-in and the AMI group was elated to receive a green light to put together an RFP. With approval from management, both agencies’ AMI groups worked with consultants to develop a plan for the project.

It was at the time of project approval that another phase of organizational action emerged that was deeply consequential for both the AMI project and the City overall. With the project approved, many in the agencies were aware that it was only a matter of time before the RFPs were drafted, after which bids would come and the AMI group would select both the technology and the contractors to install it. In the meantime, senior decision makers at both cities made moves within the organizations that they justified with the coming AMI project. At Suntown, managers acted on the shared prediction of AMI as a division-wide digital transformation that would require creative and possibly difficult structural changes to the organization of work. To that end, they turned their attention and political capital to push through a major reorganization of the division. At Fogtown, in contrast, senior managers acted on the prediction that the technologies were merely an improvement to the physical metering system. Based in this predictive assessment, managers cut off funding for meter replacement and repair, worsening an already existing crisis in the City's metering infrastructure. I next explore how these anticipatory organizational changes came to take place and their many consequences in the lead up to implementation.

IV. Anticipatory Control

Introduction

We exist in the present, but there are means through which we bring the past or future into the present. Research into the nature of agency (Emirbayer & Mische, 1998; Hernes et al., 2013) and sensemaking (Maitlis & Christianson, 2014; Weick, 1995), as well as in strategic planning (Bakker & Budde, 2012; Pontikes & Rindova, 2020) and governance (Augustine et al., 2019) has identified how through both discourse and action people move the future and past closer and further away. Most of what we know about how people engage with the future is through discourse (Dawson & Sykes, 2019; Uprichard, 2011). For example, people use "future talk" (Alper, 2019), or the future perfect tense and discursively place the future in the past as a means of sensemaking (Gioia et al., 2002). Managers use language to manipulate seemingly impossible futures into "as-if" distant realities as a means of enabling executive action (Augustine et al., 2019). Language is like a time-traveling device that allows people to bring either the past or the future into the present state.

Language is fundamental to human agency. Examples of the use of tense and vocabulary in discourse build on Emirbayer and Mische's (1998) concept of human agency as a "chordal triad" of temporality. Emirbayer and Mische defined agency as made up of three temporal elements that roughly correspond to the past, future, and present. These are the *iterational*, which is the "selective reiteration of the past," the *projective,* which is the "imaginative generation… of possible future trajectories of action… in relation to actors' hopes, fears, and desires for the future," and the *practical-evaluative,* which is a capacity of actors to "make practical and normative judgements among alternative possible trajectories of action in response to the emerging demands, dilemmas, and ambiguities of presently evolving situations" (p. 971). Thus, human agency is a "chordal triad" in which any given moment can be experienced with a stronger sense of one of the three temporal "notes" of the past, present and future, such that "it is possible to speak of action that is more (or less) engaged with the past, more (or less) directed towards the future, and more (or less) responsive to the present" (p. 972). Agency is more than discourse. There is also action. Wenzel, Krämer, Koch, and Reckwitz (2020, p. 1442) have recently indicated the need for more practice-based studies of the "*experience* of the future." Thus, the question remains as to how people anticipate the future through action.

In the previous chapter I showed how ad hoc groups of workers and mid-level managers organized a bottom-up initiation of technological change through future-oriented anticipatory trajectories of prediction, information gathering, and action. In this chapter I look to the ways in which people with power and status in organizations bring the future into the present through anticipatory control. Anticipatory systems are systems in which changes of state depend on probable future circumstances rather than only on the past or present, and thus anticipation is action that is most weighted in the future. I turn to executive action in this chapter because I found in my study that senior managers exerted control through actions that were comparably much more consequential than those of staff lower on the organizational hierarchy as a function of their position of authority. Studies of senior managers have shown that they exert control through formal and informal channels, including their use of discourse-based "declarative power" (Galinsky et al., 2003; Taylor & Van Every, 2014).

Control is a function of power, and the enactment of control has long been linked to organizational effectiveness (Katz & Kahn, 1978; Tannenbaum, 1962). While technologically induced organizational change can be an emergent, bottom-up process

(Barley, 1986; Desanctis & Poole, 1994; Leonardi & Barley, 2008; Orlikowski, 1992, 2000b), in this chapter I consider how change occurred through top-down managerial control. At both sites managers initiated changes in their organizations with the goal of better preparing for the technologies they had just approved. I show how the same technologies, depending on predictive frames developed during the early anticipation period, were anticipated by senior managers at Fogtown and Suntown in very different ways.

Anticipatory control at Fogtown and Suntown involved the enactment of two key processes: *surrogate time modeling* and *feedforward control* (Rosen, 2012). A type of prediction, surrogate time models are representations of an organization's future state held by an actor (an individual, group, or organization) in the present (Hwang & Martins, 2018; Rosen, 2012). What distinguishes surrogate time modeling from other predictions is their complexity. More than a prediction of an outcome for a department within an organization or a component within a complex mechanical system, the predictions of surrogate time models encompass system-level outcomes of new inputs and changes within a complex system. For example, instead of understanding the future of a technology as something the actor will use, or as something that will change work in a specific department, a surrogate time model encompasses the whole organizational system, predicting how a change in one department may have broader effects through the organization. Thus, people develop surrogate time models to understand potential outcomes of a change in a system's present state in the future.

Surrogate time modeling shapes action through the process of feedforward control (Liu et al., 2019; Morgan, 1992). Feedforward control is action governed by an actor's understanding of the probable future that is meant to shape the present in light of a future not yet arrived. Anticipatory systems are characterized by feedforward control, which are different from reactive paradigms in which action is informed instead by present tense conditions and governed through feedback control (Wagner & Smith, 2008; Wiener, 1956). Action informed by future states is intended to bring the present organizational state into alignment with the organization's future state. A visual of surrogate time modeling and feedforward control at both agencies is presented in Figure 4.1:

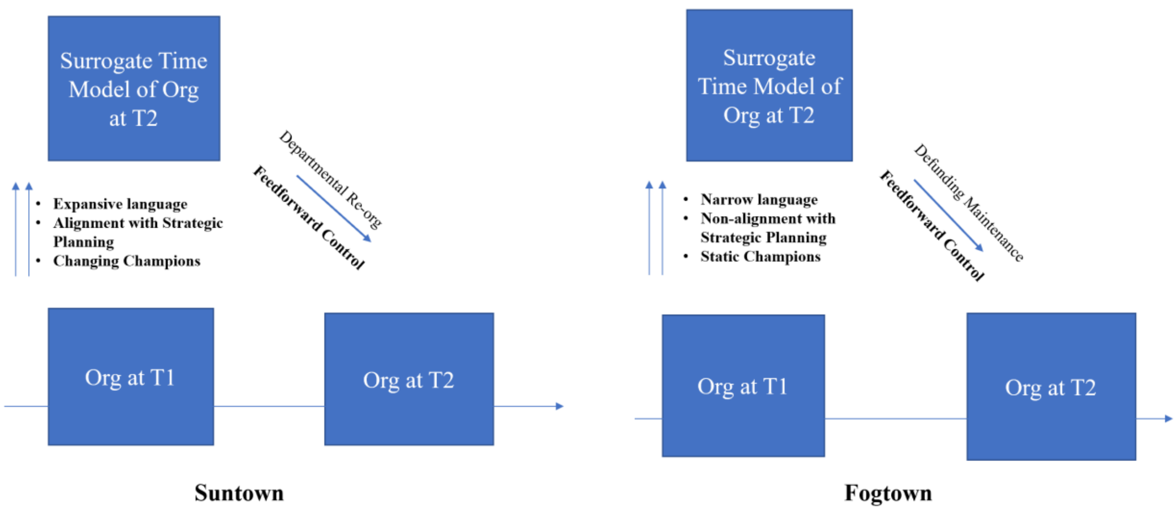


Figure 4.1. Time Modeling and Feedforward Control.

Figure 4.1 depicts a sequence of anticipatory control from Time 1 two Time 2 at both agencies. In developing their surrogate time models of the water agencies, senior managers were influenced by the predictive frames that their staff developed during early anticipation. I will show in this chapter how language, alignment with strategic planning, and the role of champions was important in shaping managers' models. As the people responsible for the whole organization, managers acted on their surrogate models by exerting control within the organization. In order to bring about a desirable outcome, managers looked for ways to adjust activities in the present, such as reclassifying employees, shutting down expensive and ineffective rebate programs, or hiring new data analysts to prepare for adoption and implementation. To bring the system into alignment with their prediction of the future, they exert feedforward control to change the organization in advance. What surrogate time modeling and feedforward control mean globally for an organization is that any action in the present state has *already* been shaped by a prediction produced by an internal surrogate time model.

The predictive surrogate models managers developed and acted on emerged from the social processes in which they engaged as part of their responsibilities as directors of civil infrastructure organizations. Both directors were responsible for maintaining complex infrastructure systems and directing even more complex organizations of people and technologies. A key function of their position was to consider the global organization by balancing out the needs of and perspectives held by individuals and groups in the various departments throughout the water divisions. Senior managers in both organizations set goals for their organizations, tweaked organizational structures and routines, and carefully considered technological change and its potential effects on the organizations for which they were responsible. As a function of their role in an organization, managers are positioned to exert anticipatory control as a means to shape the future of their organizations.

Managers at the two agencies predicted different future benefits of the technology, which meant that the feedforward control they saw as necessary to bring about a desirable future varied between agencies. The key difference was that feedforward control at Suntown shaped *organizational* change, while at Fogtown it shaped *infrastructural* change. The reason for the categorically different approach to control was that Suntown's managers understood AMI's value in its expansive data collection and reporting capabilities, which in turn led them to focus on how work needed to be organized differently. For Suntown, the benefit of

AMI was mostly centered around the data that people predicted that system would produce. In contrast, at Fogtown, senior managers saw the benefit of AMI in the replacement of broken meters with new, functioning components that they predicted would improve volumetric data collection and eliminate the maintenance backlog. The difference in outlook meant that managers at the two agencies took very different approaches to feedforward control.

Suntown’s managers enacted feedforward control through a departmental reorganization because they predicted that as a data-intensive technology, AMI warranted a major rethink of how the departments within the water Division would need to work together. To Suntown’s managers, a future in which the organization would have access to an exponentially greater amount of data meant that people in different departments like conservation, metering, distribution, and billing needed to work together more closely to analyze and act on the new data. For example, anyone engaging in customer service needed to be up to date on what kinds of reporting would be most useful to customers, or what data was most useful to encourage conservation behavior. This could be achieved by a departmental reorganization. In contrast, Fogtown’s managers were more focused on the need to replace an old and failing meter system. They were less impressed with the kinds of data AMI could produce and did not ask questions about who needed to work together for the technology to succeed. Thus, Fogtown’s managers exerted feedforward control that shaped infrastructure in ways that they predicted would best prepare the system for meter replacements.

Making the Future Happen in the Present

Like most water agencies in the United States, Suntown and Fogtown were organized as traditional hierarchies. There were clear divisions between departments within the water division, and channels of communication and responsibility were explicit. As one supervisor put it at Suntown, “We’re not… what do they call it? Flat? Things around here are pretty old school. We follow chain of command.” This meant that, as we saw in the last chapter, that information seeking and organization action around AMI had a bottom-up, grassroots energy behind it, there came a time when senior management was ultimately responsible for changes within the department. In this chapter I explain how in approving the projects to move forward, senior managers moved from the periphery at both agencies to the center of the AMI projects. They took it upon themselves to exert control and prepare their organizations for the coming technological change.

The direct involvement by senior managers ushered in a new period, which I refer to as *anticipatory control*. In taking executive action, senior managers attempted to align their present-day organization to the needs of the AMI-enabled future they predicted. Events and their consequences during anticipatory control are significant for the primary reason that the reach and leverage of senior managers surpassed that of people beneath them in the organizational hierarchy. Informed by their own surrogate time models of the agency’s AMI future, senior managers altered their organizations in consequential ways. There were two key differences between managerial action and that of their subordinates. First, managerial action was top-down. Senior managers made decisions without consulting their staff. A second difference was that action during this period was more far reaching and consequential than the organizational actions taken by members of the ad hoc AMI group earlier. Senior managers leveraged their positional power within the organization to push through changes that had broad effects throughout the organization. While senior managers had been kept abreast to varying degrees about AMI-related activities at earlier times, it was not until anticipatory control that they took it upon themselves to exert feedforward control to align the present state of the organization to anticipated future events.

At Suntown, action during this period consisted of a major departmental reorganization that affected job titles, salaries, and the structure of work within the department. At Fogtown, the decisions made by the director abruptly cut off departmental maintenance budgets, which hastened the deterioration of a metering system already in decline. Worsening meter failures strained work and interactions between departments in the department. Later, the effects of the reorganization and the block on meter repair were important to the overall process of technologically induced organizational change because they produced the conditions under which the agencies subsequently selected for and adopted AMI.

Anticipatory control consisted of two phases of activity. In the first, senior managers developed surrogate time models of how AMI would change their organizations. Suntown's director's model was based in the understanding of AMI as a complex digital transformation that would require significant organizational change to succeed. In contrast, the Fogtown director's model was of a more limited substitution of an updated technology for an old one that would not fundamentally alter organizing at the agency. Both senior managers' models were shaped by the way their staff talked about, positioned, and championed the technology. Important to predictions in this phase was the co-occurrence of strategic planning processes in the agencies that were led by both senior managers. While the processes were similar in many ways, only Suntown's incorporated AMI as a central factor in the agencies' long-term goals. As leaders of the strategic planning process, Suntown's managers incorporated AMI into the decisions they made for the future of the agency and positioned the technology as an important part of reaching their goals as an organization. In contrast, Fogtown's strategic planning process progressed as a separate and disconnected trajectory.

Phase 1: Surrogate Time Modeling

For managers at both agencies, surrogate time models were the predictions they developed of AMI within the total organization for which they were responsible. Managers looked to their staff for information about and perspectives on AMI. They applied information they gained from staff to their own specific and actionable understanding of what AMI was and how it would be used at their agencies. An important early factor during managers' development of surrogate time modeling was the degree to which they conceptually aligned AMI technologies with the strategic planning they were directing at the same time. The degree to which AMI aligned with strategic planning depended on at least three factors: (1) the language used when talking about AMI, (2) the way in which AMI was positioned in relation to strategic plans, and (3) the degree to which the role of project champion shifted between actors over time.

Language. The language actors used to talk about AMI was important in shaping how others came to understand what the technology was and what it would be used for. With departmental approval for the projects came opportunities and responsibilities to present and talk about AMI with others, and at both agencies, members of the AMI workgroups increasingly shared information about and their perspectives on AMI in conversations, over email, and in departmental newsletters. One of the most distinct ways in which language differed was in terms of scope. A broader scope meant that people talked about how AMI had wide-ranging potential applications. A narrower scope limited descriptions to the meter-to-cash process. At Suntown people used language that painted a very broad scope of implementation and use for AMI, while Fogtown used much more narrowly-scoped language to describe the technology and its future use.

Suntown's AMI Language: A Broad Scope. Upon first learning about AMI, Suntown's ad hoc AMI group developed an expansive predictive frame about the technology. Multiple sequences of information seeking and organizational action helped them to shape an understanding of the technology as wide ranging in its uses and effects. They predicted both a longer implementation timeline during which the agency would learn to use and reap the benefits of the technology and some degree of organizational restructuring to succeed in the transition. In developing early predictive frames, key staff underneath senior managers had accessed outside networks and been exposed to information about the many nuances of the system's constitutive technical components and how each interacted with one another as a total system. This meant that, on one hand, they had a deep understanding of the integration between AMI's components and the existing technologies on site, and on the other they actively sought out information about the ways in which they would reorganize work to benefit most from the transition to AMI. The language staff used around managers reflected this broad understanding. For example, Peggy summarized the project in an interview in this way:

> I am going back to trying to bring like the customer service aspect of AMI and tie it all together to keep people engaged and excited about it. This isn't just about a technology change. This is about a cultural shift in the organization.

Peggy's use of the term "cultural shift" was intentional. When talking about AMI with her colleagues, she worked to underscore the broad scope of changes that would be necessary to make AMI successful. As Peggy recounted to her team, AMI was not just a simple technological upgrade; rather, it was a complex process that required that Suntown rethink how it organized its workers to more effectively manage its water. Customer service was important to Peggy because it was an important part of her job to build a positive relationship between the department and residents in the service aera. She knew that to improve customer service she needed to expand and engage the billing staff more directly in the AMI project. By using language about AMI like "cultural shift," she distinguised AMI from other, more limited technologies that her audience might have experience with. The expansive use of language at Suntown contrasted with the more limited way of talking about AMI at Fogtown.

Fogtown's Language: A Narrow Scope. In contrast, at Fogtown the staff who worked to bring AMI to the agency through participation in an ad hoc group developed a shared predictive frame of AMI as a technological upgrade that would be mostly limited in application to the meter-to-cash process. The staff was aware that the City Council was sensitive about running afoul of a politically-savvy anti-5G organization in the city. The organization was actively protesting the installation of any 5G technology in the City, but in the past had also been one of the main drivers behind stopping an earlier desalination project. Many in the Water Division were confident that anything that sounded like "smart metering" would catch their attention and become a target of organizing. Activists were already leaving flyers on Water Division cars outside of the main office. Figure 4.2 below shows a flyer left on staff's vehicles:

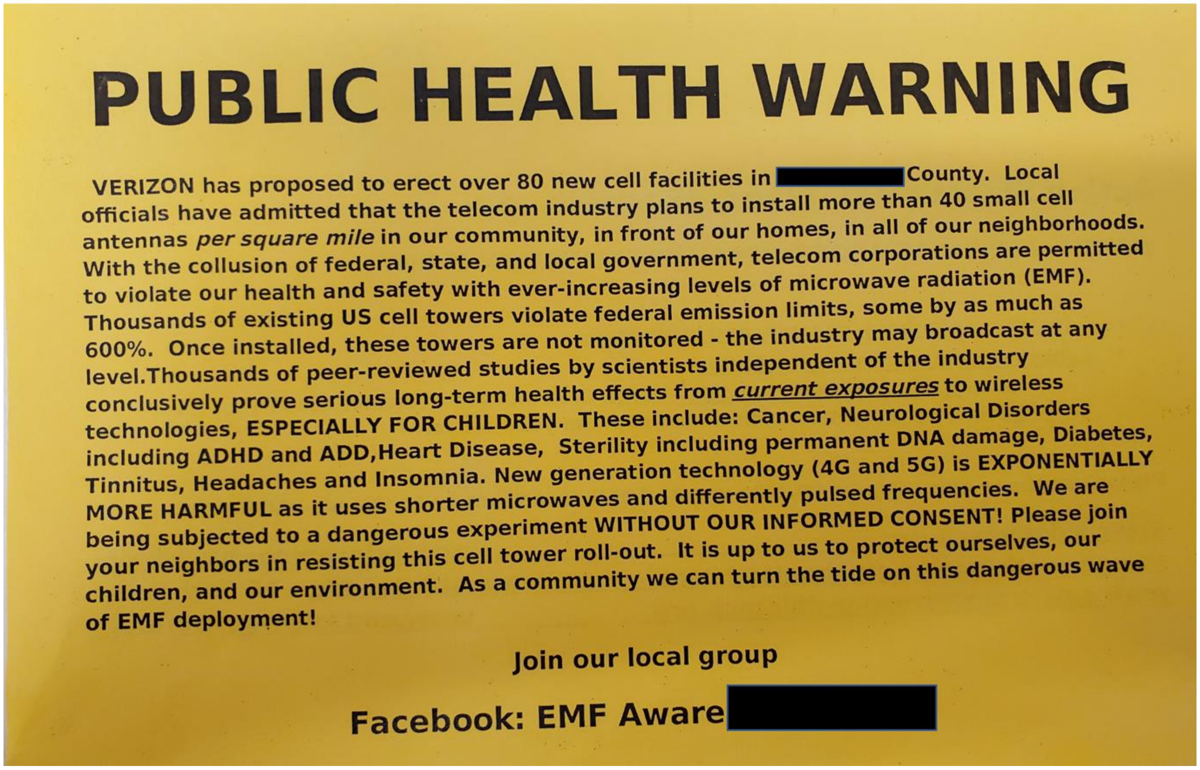


Figure 4.2. Flyer Left on Staff's Vehicles.

The group that distributed the flyer held regular meetings and attended monthly City Council meetings. The threat of their derailing the AMI project made staff inclined to use language that downplayed the technology and the changes it would bring. Instead, their language tended to paint AMI as a limited technology with a relatively short timeline of implementation that would not require organizational change, characterizing it as a simple substitution of the existing meter system. The adopted name of the project indicated this reduced scope. Unlike at Suntown, where the project was referred to as "AMI," Fogtown's workgroup named the overall effort a "meter replacement project." Evan explained the strategy of downplaying the technological novelty and complexity inherent in the project:

> So it was originally titled Advanced Meter Infrastructure Feasibility Study, right? And after we presented, because of the whole 5G thing, we really changed the nomenclature around it all and said, "All right, let's not even talk about anything advanced or metering really." It sounds kind of techie. We'll talk about it in really kind of like what construction terms into a replacement project…. To this day, we don't really play up the software aspect. We're really kind of emphasizing that we're almost replacing in kind, just taking old meters and old radios out and putting new meters and new radios in. And oh, by the way, these radios can do daily reads. It's like an afterthought.

Evan and his colleagues believed that downplaying the "techie" side of the project made it more likely that they would be able to get both departmental and city council approval. Evan and his group sought out a path that would avoid controversy, and in their experience, new technology was controversial. The group did not, however, think that the public perception of the project would limit their ability to benefit from the technology in the future.

Within the AMI workgroup, some of the staff from the conservation group were learning about how to use interval data to improve conservation programming, but they also downplayed the data attributes of the technology. Adam, a conservation coordinator, talked about the language they used for the project in an interview:

> Now under the framework of meter replacement project we'll be updating to AMI devices. But we're framing it as a meter replacement project, not an AMI project. We'll get all the benefits of doing AMI without calling it that.

Like Evan, Adam saw hope for the approved incarnation of the project in its characterization as a "meter replacement project." As a conservation coordinator, he hoped to use the interval data to improve conservation efforts, but he explained that he expected to still reap those benefits without promoting them as part of the project. Hope, the director, acquired her staff's inclination to talk about the project as low tech, explaining, "We never, ever call them smart meters. We stopped that immediately." Thus, no one at Fogtown talked about AMI as very technological at all.

The language the two AMI workgroups used when they talked about the AMI project during this period was important because it shaped how the technology became positioned with other activities and projects within the organization. While individuals within the workgroups might have had a different vision of the project than they presented, like in the case of Fogtown, decision makers above them in the organizational hierarchy did not always appreciate the technological potential and complexity of AMI when it was hidden from view. This became particularly important in relation to ongoing strategic planning efforts at both cities.

Positioning. Differences between the strategic planning processes at each agency and the relative position of AMI to these efforts differed in ways that shaped both senior managers' understanding of the technology and of the degree to which the anticipatory control they set in motion was focused more on the organization or its infrastucture. At Suntown, language with a broad scope caught the attention and energy of senior managers who were already in the midst of facilitating conversations about strategic change at the agency. Conversely at Fogtown, language with a limited scope did not position AMI as important in relation to similar higher level strategic planning work that was underway. Strategic planning was important to the senior managers who were the primary drivers of the processes at both agencies. The purpose of both processes was to orient the agencies towards the future and make changes to unite departments' efforts towards a common goal. The planning processes involved multiple large group meetings facilitated by third-party consultants, consisting of assessment, visioning, and planning sessions that produced a set of agreements, goals, and supporting documents that actors within each agency could use and refer to in their work. The activity during positioning shaped the eventual place of AMI in the organizations' larger change management processes.

Suntown and "OneWater" Strategic Planning. At Suntown wastewater, production and distribution were historically separated into distinct and sometimes unconnected departments with different cultures, practices, and salaries. Wastewater work, for example, was paid less than production. Suntown's strategic plan to unite work across departments was called OneWater. To achieve the goals of the OneWater vision, the agency would need to radically alter the structure of work within the organization and find ways to adjust salaries and work practices to "bust siloes," as one report put it, and unite their efforts. The vision of OneWater was easily understood by diverse actors within the agency such that actors throughout the organization often referenced the OneWater project and talked about their work in the context of the organization's overall mission.

The OneWater program was developed by an industry association and adopted by many water agencies as part of their long-term planning processes. Suntown's planning participants talked about the OneWater program as an effort to create a paradigm shift in how the agency was organized to manage water. Esteban, the lead meter reader, mentioned the effort during an interview: "…this OneWater thing. It's getting rid of a lot of the ways we separate work in the department. Sometimes Peggy asks me to do OneWater work so I get involved here and there." As a meter reader, Esteban was not deeply involved with the ongoing OneWater meetings and activities, but he was aware that it meant that there would be changes to how the department was structured. Much of the shift Esteban mentioned involved uniting long-siloed water management work to treat all water, whether it was wastewater, rain, or recycled, as equally important resources to the agency.

The OneWater strategic planning process was supported in the early phases by outside consultants, but a diverse group of actors at the agency met monthly to assess and implement the strategy throughout the agency. Many in Suntown recognized that droughts in the region were becoming both more frequent and more intense, and as the agency responsible for producing potable water for their service area, they looked to OneWater planning as a place to reimagine how they treated the fragile watershed. A summary in a communication document from the agency described the program as follows:

> The City of [Suntown] is implementing an important initiative that integrates the value of *all* water into *all* City operations. This means that all waters—wastewater, groundwater, stormwater, seawater, and surface water—have an important role to play in [Suntown]. This initiative is called One Water [Suntown] but it doesn't just end with valuing water in varying states. One Water is a holistic approach to water management that takes into consideration all the various ways water impacts our lives and the community.

The description touched on two distinct areas for change. The first half of the statement summarized a straightforward goal for the physical resource of water that all states of water should be valued equally, and the second pointed to a new approach to management. Many understood the first aspect to be a project around conserving and recyling water, and seeing wastewater as a resource rather than something to dispose of. Fran, a water resource specialist who worked in the field with customers, connected the OneWater program to her conservation work:

> So my specialty is actually how much water to apply to the plants in designing irrigation systems. Coming to the city, I have learned more about toilets and urinals and indoor leaks, but it's all water. Water has one function; it moves. It provides pressure. So it all ties together, all the different aspects of water. The new buzzword is OneWater. And it's true! So our goal is to get people to recognize that what they put down the drain also goes back into the water table in one way or another and to be as conservative in that aspect and reusing the actually potable water that they already have. Kind of cool.

In this way, the concept of OneWater was an accessible framework that related to individual actors' day-to-day work. Fran easily connected with the idea that all water was equally important. The vision statement's second part pivoted to a goal of a "holistic approach to water management." This part identified that in order to achieve their new approach to managing water, the agency needed a more "holistic" management approach. The idea of restructuring work in the department was intuitive for many when they talked about it in the context of disparate departments within the division. Camilla, in the conservation department, talked about OneWater:

> It's basically organizationally looking at all water is water, whether that's potable water, wastewater. We are just trying to connect the organization to all make it one group instead of silos. I think the conservation group has always kind of had that view, because a lot of us already do water work and wastewater work. Like for Janet and me, both of our jobs are very heavy also wastewater. I think maybe that's not the feeling in other groups. There are people in a literal silo up at the [Pelco Reservoir] or in Water Quality. They're in their little camps. So, it's trying to make everything cohesive and one team working together for the same goal, especially when we go into potable reuse, where our wastewater becomes our drinking water, so it's that whole concept.

OneWater made sense to Camilla because she experienced the siloes between different departments within the water division in her own work. Sometimes she worked with purified water in distribution, and sometimes she worked with it as wastewater. She easily linked the idea of uniting states of water under OneWater with uniting departments within the division. Camilla was not alone in this association. Many workers throughout Suntown often compared goals for the physical resource of water to the structure of work within the agency both in observations and unprompted in interviews. The similarities between how actors understood OneWater and AMI made it easy to position AMI as a necessary and important part of that process.

Members of the ad hoc AMI group at Suntown positioned AMI as a technology that, like the goals of OneWater, required a new approach to water management. One way they positioned the two together was by emphasizing future changes to work practices. The workers who were most aware of how complicated the meter system was and what new skills would be needed to manage an AMI system were the meter readers themselves. When Suntown's meter readers talked about AMI, they often pointed to the new kinds of work it would take to capture the benefits of the system. For example, Cameron, a meter reader, talked about AMI as a complex system that would be successful only if people in the organization had the skills and directives to use it correctly. As he observed one day during a routine meter check,

> The thing with AMI is that I've seen technology can save you time, but only if you use it correctly. Like, I work for Home Depot part time. They used to have a basic inventory system there that worked well. But then they upgraded the system and they could track the details of everything—every foot of rope sold, every square foot of wire, how many bags of soil, how many screws, nuts, soil. It's awesome—you can get a lot of data from it—but you can get sucked in to trying to manage that data, because your inventory is never going to stay perfectly accurate. All the time you save by having your data tracked, now you're paying someone to manage it and make sure it's accurate. So there's this fine line of how do you balance that out.

Cameron's observation expressed a sense of the ways in which more data can produce more work. He was skeptical that an automation technology like AMI would produce labor savings. The approach to the new data produced by the technology at Home Depot was one that required a bigger organizational rethink than simple substituion of a new technology for an old one.

Peggy, Cameron's supervisor, made clear a similar understanding of AMI in her communciations with senior managers. Peggy often played facilitator between the AMI consultants and senior managers. In one of these meetings, she opened up the conversation by prompting the consultants to tell the managers about their experiences with organizational change after AMI:

> Obviously we realize with AMI that the role of meter readers will change, but cutting positions and layoffs aren't what we want to do. We've been studying how to streamline our customer service. Conservation and billing and meter reading all do customer service and we want to understand the evolution of the meter reading position and understand what positions we need to have in place to maintain this system to pull the data, actively use the data, and get the most out of it. We want to understand your experience from other utilities of what worked well, what plans changed, and what from your perspective is most effective in managing this organizational change.

Peggy understood the interests of the senior managers who were present and positioned her questions to mirror the central concerns of the OneWater process: how to better organize work to meet future needs. Peggy's understanding of managers' interests in out-of-the box thinking about the structure of the division as a whole led her to emphasize the potential for AMI to support restructuring. If AMI were an important technological component to the ongoing drive for greater unity across departments, senior managers could help carry AMI forward as a high-status project. Her prompt to the consultants helped position AMI in line with the interests of senior managers in attendance.

Fogtown and AMI's Peripheral Postion to Planning. Fogtown's water division manager initiated a strategic planning process around the same time as Suntown's, but it differed in many ways with regards to how it was developed and its usefulness to participants. In contrast to planning activities at Suntown, the strategic planning process at Fogtown was limited to a series of events and surveys facilitated by outside consultants that did not continue after the participatory planning sessions. Consultants facilitated a several-days-long series of "external scan" sessions during which participants brainstormed what events outside the organization may impact their work and how they might prepare for the challenges ahead. Hope described the purpose of the process and how staff would get involved in her "Director's corner" column of the weekly newsletter:

> Step one of the [strategic planning] process is an effort that is going to engage a lot of employees in something called an External Environmental Scan. In four groups of 15 to 20 employees each, we're going to be asking employees about what they see as the external forces, factors and trends that are now and will in the future likely affect us and the work we do… The purpose of exploring what's changing and shifting in our external environment is to ensure that our strategic plan is truly strategic and responsive to all the forces that may influence us. This means making sure to look at our world from the "outside in" and not just from the "inside out."

Hope's update described a process of improving the work the department already did by assessing how the environment might change around them. For Fogtown, the mission of the organization was already clear, and through strategic planning her goal was to collect input and ideas from her staff to make improvements. Missing from the work during strategic planning were any discussions of major organizational change. Because Hope organized the strategic planning process as a series of open forums during which staff could raise any and all concerns about the organization, many of the sessions were dominated by the airing of grievances, of which there were many.

Over the course of this study, Fogtown staff and their supervisors rarely mentioned the strategic planning process. When asked how they had participated in it or their sense of how it affected the organization, many were critical. For example, Julia, a customer service supervisor summarized the process in this way:

> Oh god. I really don't think it was all that successful. For all the work we put into it, and all the documentation and kind of goal making and whatnot that came out of it, I don't think that the record would show that it did all that much. You know, some of it was, was designed, I think, to just you know, just improve the way we work with one another.

Julia did not describe the process as one that was either useful or intended to make many changes in the organization. In fact, the issue about which most staff were concerned and that received the broadest support for change was around increasing staffing and raising salaries. Fogtown's cost of living had increased tremendously in the last decade, and many staff struggled to support a middle-class standard of living or save enough to ever buy a home in the city or surrounding areas. As one person put it during the planning sessions, "Being blue collar in [Fogtown] is tough." The notes from planning meetings and quotes from anonymous surveys show a broad resentment around staffing levels and pay. One disgruntled respondent listed a litany of common complaints:

> Please remember when trying to fix our department's staffing and morale issues that the forces that have been negatively affecting it have been in play for a very long time and cannot be fixed with some interviews and surveys. Employees went years without pay increases, then got a decent contract in 2007, only to be forced to give back most of that contract within a year and lose even more over the last 9 years. Dedicated employees who truly care about the department and the people they serve have stuck it out, but they are starting to retire. So please figure out a way to attract, retain and PROMOTE good employees from within. There is a lot of talk among employees about how the department and city seem to be hell bent on finding new outside talent rather than promoting from within. Seems like encouraging growth and promotion, especially when unable to pay a decent wage, would be a no-brainer.

The anonymous commenter described a situation in which the pay and staffing were bad and which, with coming retirements, would only get worse. People in strategy sessions referred to an expected wave of retirements as a "silver tsunami" that would drain the department of valuable experience and skills that current pay scale would likely be unable to replace.

The lack of attention to what many saw as a fundamental problem was the basis of much of the resentment that surfaced during planning. As an example, in answer to a question on a survey that accompanied the planning process, one respondent said, "What do we need?? More staff, more money, more payroll, more appreciation, a pat on the back, a thank you, a company picnic." When staff organized comments about staffing and pay into a formal proposal to management, however, they were blocked from moving forward. As one supervisor explained:

> So we turned [the wage study proposal] in, and we're about to have all of these things packaged up and sent back out to staff in the next day or two. I mean, it was literally that we just hit it on deadline. And [the director] says that at this point that we have to drop the whole process. She said this isn't going to happen. We were like oh, wow. What the fuck was the point?

As a consequence, many wondered why they had been asked to participate and share their opinions and hopes during the process. A mood of distrust and skepticism surfaced during the planning process among many of the participants. Consultants reported the negative feedback they received during another survey:

> Rumors: Some expressed concern that what this Strategic Planning is "really about" is consolidation with the Wastewater Department, or "downsizing."
>
> Skepticism: "Studies like this are a waste of time and money in my opinion." "You're kidding yourself if you think there is anything "scientific" about this survey."

Hope and other senior managers indicated that they understood that there was frustration and skepticism about the strategic planning process. To communicate this, they distributed a written response to staff indicating that they heard and valued their comments about "retaining qualified employees, knowledge transfer and succession planning, and how we're going to meet our workload needs in the coming years." The overall planning process, however, was brought to a close. Unlike at Suntown, there were no ongoing meetings or strategy sessions to move the organization towards the goals identified during the process.

In light of how contentious the strategic planning process was, the AMI group did not position their project as central to the effort. In fact, the same people who were pushing AMI forward were the ones consolidating participants' concerns about wages into a report. During the large brainstorming sessions, the topic of AMI was raised, but it was one topic of dozens of "external" issues discussed. In the few examples when Hope referred to AMI in relation to strategic planning, it was in the context of how technology could "help them to achieve their goals," rather than how it could be a force for change within the organization itself.

Consequently, AMI and the strategic planning processes progressed on separate and parallel trajectories. During the six months during the strategic planning process, rather than positioning AMI as somehow related to the bigger planning process, members of the workgroup continued to position it as a swap out of components. The meter shop submitted an update on their troubles with the system in a division-wide newsletter:

> Speaking of meter reading woes, Evan is working up a full inventory of our radios—serial number, model, date of manufacture—to look at aging, failure rates, and schedules/costs for replacement. As you might imagine, what's out there ranges in age (0 to 16 years old), model, and reading type (drive-by, touch, AMI), and it's all pretty much mixed in together. This scattershot inventory is the result of a simultaneous obsolescence (planned?) of older stock and the introduction of AMI reading technology. Basically, as each older radio dies, we replace it with an AMI radio because a) [Acme] doesn't make or support the old stuff anymore, and b) they'll sell you a new AMI radio for less than a drive-by radio. Little by little, radio replacement by radio replacement, we get further into bed with a proprietary technology and infrastructure that we already have mixed feelings about. What to do? First thing's first: figure out exactly what you have out there.

This example shows how the AMI group did not adjust their discussions of AMI to position it differently. The approach of this excerpt contrasted with Suntown's "cultural shift." By using language like "radio replacement," the meter shop presented AMI to others as a different version of the same components already in place.

When asked about the successes and changes that came out of the strategic planning work, Hope's reflection was of a missed opportunity for organizational improvement. She blamed the lack of ongoing strategic planning on longstanding divisions among departments:

> Reflecting on it now, I don't think the strategic planning was all that successful. I wouldn't say that the work we did here was very collaborative. It didn't break down the barriers within this organization that have existed, as often exists between operations and engineering. For the operations group, it's like never enough whatever you've done for them. It's never enough. I think that's part of our organization dysfunction that is persistent. Sometimes you can only make better progress once people who are really resistant retire.

Hope's comment in part revealed her general frustration with the "operations group," of which metering was a part. Her regret in being unable to facilitate a successful strategic planning process centered on what she perceived as longstanding disfunction that could only be improved with time. Hope never evidenced a perspective that included technology as a way to improve or change organizational structure to benefit the agency overall.

Champions. A third factor that shaped how AMI aligned with strategic planning was the role of the project champion. At Suntown, the role of project champion was dynamic and unfixed. Different actors represented and promoted AMI at different times, which enabled the project to garner support and interest from a wider range of decision makers in the organization. In contrast, at Fogtown, the original AMI workgroup stayed much the same, which meant that the face of AMI was unchanged over the course of several years. The differences in project championing shaped how decision makers came to understand what AMI was and therefore what action was necessary to take in anticipation of its adoption.

Suntown's Shared and Shifting Champions. New champions of AMI emerged in this period. The effect of shifting champions was that the future of AMI could develop as something that was not relevant to a small group of people in the orbit of a single and constant project champion. Where Peggy and her supervisor David were the primary investigators of AMI and coordinators of its advancement in the early days, they took a back seat during the control period. One reason was that both received promotions and became busy adapting to their new roles and expanded responsibilities. Renee, a superintendent, described how she and the other superintendents had required Peggy to step back from AMI as a condition of her promotion:

> For Peggy, [AMI] was her baby. She thought I brought in other people to take over from her. It was like I was ripping the baby out of her womb, she was just so devastated. And she made up her mind that she was going to be the project manager and [her hourly assistant] Sam was going to be the assistant project manager. [That's how she thought] it was gonna roll. I'm like, No, no, no, no, no, no, no, no, no, because you reach a point where you develop something so far, then you hand it over to somebody else. That's how you roll with it. And especially, where now she's taken on this promotion of the superintendent. Well, there's no way in hell that she could also still managed to do that.

Renee's use of a graphic comparison to "ripping the baby out of her womb" shows how the practice of shifting champions was not initiated by the original champion herself. Rather, senior managers required middle managers like Peggy to let go of their pet projects and let others move it forward. As Peggy's superior, Renee emphasized that part of the process of developing professionally in the organization was learning how to let others advance projects to completion. In Renee's opinion, Peggy was unhappy with the change at the time, but Renee confided that she expected Peggy to understand later why it was necessary: "If you can empower people to let go and grow, I mean, I think that that's gonna be a huge game changer."

With Peggy taking a back seat, Renee asked Camilla, who was a promising young staffer from the conservation department, to take the reins and made the project her own. Camilla had never managed a project like this before, and she approached it with both anxiety and excitement. Camilla described her response to being asked to step up:

> AMI metering has been Peggy's child forever, but now there's all these changes in our group. Peggy's kind of acting in a higher role now and my take on it is they're basically like, "You have to let go of some of your projects so that you can be more of a management level."

> It is really exciting. I'm super nervous because it's a huge project. So I'm really excited that I was picked for the opportunity. I'm really nervous but—there's always that feeling of, "What if I fail?" [laughter] But no, I'm excited. It's just going to have to take a lot of shifting around with my other job responsibilities because this is going to take up a lot of time. And that's the part that's intimidating to me about becoming project manager for this is it's kind of freaky thinking that I'll be in charge of this when I don't feel like I a hundred percent understand everything, yet.

Camilla soon began chairing weekly meetings to develop the agency's AMI request for proposals. She was a quick study and within a few months was confidently coordinating the effort.

Others saw the shift in the role of champion as a sign of the AMI project's maturity and durability. With people from other departments showing that they understood and could lead it, the technology appeared more relevant to a broader set of departments. In interviews with Camilla's supervisors and peers they often commented on how well Camilla had adapted to the role. This indicated senior managers' confidence in the fact that the project was robust and not dependent on the energy of a single champion, and it allowed for others to take on responsibilities without worrying if they were stepping on Peggy's toes. Manuel described the transition in this way:

> When the bosses asked me to support Camilla and help keep the project on track, I was like, "Better go talk to Peggy! [laughter]." Make sure she's okay with it. Because it's her baby!" And she was actually perfectly fine with it. There are new people from conservation getting involved and I think it's really good for the project.

Manuel's comment demonstrates how his earlier sensitivity of working on a project that he saw as "Peggy's baby" receded once she acknowledged her new role and made room for others to get involved and feel ownership over the project.

It was at this time that senior managers became more vocal champions of AMI. George, the director, and Renee both represented the project to their peers as a project that had broad support across numerous departments. People had seen Peggy and Camilla representing the project, so to others it was clear that it was not limited to a small group within metering or conservation alone. Importantly, the enthusiasm with which George as the most senior manager in the entire division took up the role of champion was an important signal of his strong support and confidence in the project to both his peers and elected officials. As manager, George represented the project and gave updates to others in the larger municipal organization in which the agency was housed, including the director of public works and the City manager, the Water Commission, and City Council. Any information or feedback he got from those encounters was useful for the workgroup in their efforts to keep a finger on the pulse of decision makers whose opinions could spell the success or failure of the project down the line when contracts would need approval. In the following quote, George related a conversation he had with a representative on the Water Commission:

> I have talked to a few commissioners. One comment from James Frank on the dais during the water conservation strategic plan in November seemed important. He made a comment "I'd like to see more 'real time' in this AMI." We've talked about that, but it sounds like the systems aren't quite to "real time" yet. Maybe a good idea to follow up with James at some point.

James, the water commissioner, did not know much about AMI, but he expressed to George that the real-time data access seemed especially useful. At the time, the Suntown group had learned that pings every 15 minutes was the shortest interval available that would not drain the devices' batteries, but George advised them to keep James's comments in mind and reach out to him to talk more about what AMI could do.

George planned ahead with the workgroup for future events to engage the agency in the project. When George strategized with meeting participants during an AMI check-in at a customer service meeting, he talked about a meeting he had with the City Manager, Vincent, and brainstormed next steps:

> So the conversation that Vincent and I had was that we really want to make a big deal about [AMI] when the public is going to start being able to engage. We shouldn't bring it to Council until it's something the public will experience. We don't want to get out there in public too early. Another thing to do before then is an all hands meetings. I would welcome doing something similar for water resources and I could disseminate info on what's going on. I'm trying to figure out what's the most digestible—have a meeting and record and share the recording? I think there are a lot of different opportunities, so I'm looking forward to hearing what you come up with.

George's role is useful in this example because people like Vincent and representatives on City Council were otherwise out of reach to others in the AMI workgroup. Suntown's water agency operated with a clear hierarchy, and staff were expected to go through their higher-ups to get things done. Here we see that George worked behind the scenes with the City Manager to strategize the best time to bring the project to council with a detailed report on the project. Once the group presented a more involved update to council, it would enter into the public sphere and customers would begin to hear about it. Thus, George advised that it was better to wait until they were more clear on details about how the customers would use and experience the transition.

Shifting champions at Suntown was important because it made the project more mobile across departments. Not only did the face of the champion shift from metering to conservation, but it also shifted up to senior managers when they met with and talked to representatives on the Water Commission and City Council. The process of opening up the role of project champion was not easy, as Peggy at first resisted the mantel being taken from her and given to a subordinate. The more people who were championing the project, however, the better it was for the project. The project became *bigger* than just how early proponents had perceived it. In contrast, Fogtown's champions project was a case in which the role of champion remained stuck in the starting block, unchanging as time progressed.

Fogtown's Unchanging Champions. At Fogtown, if people throughout the agency had heard about AMI, they often knew more about who was involved with the project than what it consisted of. As Jeannine, a customer service representative, put it, "We've seen a few presentations on the AMI thing, but that's much more a Hunter and Evan thing." Jeannine's comment reflects a common perception of AMI as a project that belonged to others in the organization. In a survey of the metering, customer service, and engineering departments of the agency during this period, a small number of respondents expressed that they knew what AMI was, or that they expected it to be relevent to their work:

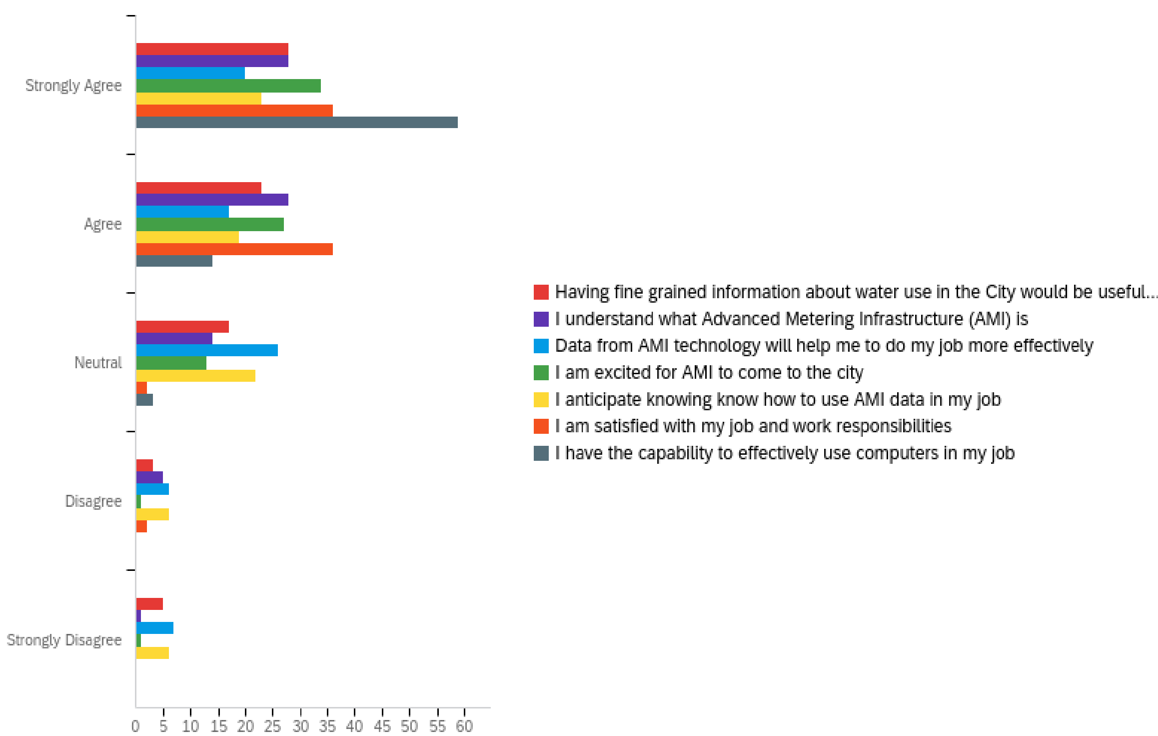


Figure 4.3. Attitudinal Responses to AMI.

While most of the 55 respondents reported being excited for AMI to come to the City (n = 39), about half expressed that they anticipated that AMI would help them do their job more effectively (n = 24). Despite the overall positive sense of AMI, many seemed not to appreciate or understand the data implications from AMI or how AMI might relate to their work. Data-related questions were the only relatively strong "neutral" responses. This suggests that most people perceived AMI to be a metering technology that would impact metering, rather than other areas of work in the department. Respondents thought of AMI as "infrastructure" rather than as a valuable and extensive data resource with wide applications.

Hope did not champion AMI to others at the City over the course of this study. Positioning it as a meter replacement project, she treated it as she did any other activity related to metering. Hunter reported that he and other workers in the meter shop felt that she was an absent director:

> Hope has never once been to the meter shop. We are an afterthought even though we're where the money comes from for this department. Without the [AMI] project now, we'd be nonexistent to her. And in some ways we have enjoyed the anonymity that came with that, but now when we have a problem we have to wave our hands around.

The meter shop's position as outsider had come with benefits in the past, as the meter specialists could do their work with little interference from senior management. Their distance from the rest of the agency was physical as well as programmatic, as the meter shop was a small office several miles from downtown next to a pumping station. Hope had never visited their office, but this had not bothered them until they needed her support to get the project the attention and funding it needed to be successful."

AMI was not one of Hope's priorities in working with her colleagues and higher-ups within the municipal organization. When asked about her involvement, a superintendent in the engineering department described Hope's priorities in the following way:

> The AMI Project, I think, is a really good example of how priorities shake out here. All the other capital projects and staffing, organizational structure, and things like that

> are—I mean, those little areas where a director has to ask "Am I going to champion that?" AMI is not something that I've heard her talk about.

One way this absence was notable was in a weekly newsletter that she sent out to the entire Water Division every week. Each department contributed a small update for their colleagues about what activities and accomplishments had occurred over the past week, and almost every week Hope composed several paragraphs at the top of the newsletter to call out specific individuals and efforts that were important to the division. Hope never once promoted the AMI project in the newsletter. Instead, her updates included congratulations and updates on major engineering projects, strategic planning initiatives, budgetary cycles, customer service improvements, and administrative activities. The only mention was in a single line late the process:

> …and Evan, well, because between covid, water restrictions, rate increases, and AMI I'm convinced he no longer sleeps.

In this comment AMI was one of several things keeping Evan busy. It is apparent from this single line in years of newsletters that the director did not connect AMI to her larger visions for change in the agency.

Activity in this first phase affected the trajectory of technological change in two ways. First, the nature of the role of champion, combined with the position of AMI as related to strategic planning and the language used by AMI's promoters, shaped the extent to which AMI became positioned as a driving force for change. At Suntown, senior managers talked about and promoted AMI as an important facet of major organizational change already underway. At Fogtown, the director did not engage with the AMI project. This meant secondly that senior managers operated on a version of the future that then triggered anticipatory action. What that action was and how it was carried out is the topic of the second phase of control.

Phase 2: Deciding On and Enacting Change Through Feedforward Control

For managers at both agencies, feedforward control was the means through which they changed their organization in the present to align with their predictions of the future. The changes they induced were top down and closed off from subordinates. The rationale for decisions was opaque to anyone outside the inner circle of senior managers. As a consequence, the control exerted by senior managers at both agencies caused the people affected to be both outraged and confused by the directions their managers had chosen. As feedforward control was shaped by managers' predictions, the nature of the control at each agency was very different. At Suntown, managers made decisions about organizational change that they thought reflected the future of a more integrated and data-driven water division. At Fogtown, decisions affected the agency's metering infrastructure to prepare for the replacement work ahead. Action began with understanding.

What was AMI for Senior Management? In this second phase managers developed an understanding of what AMI was and decided on a course of action for their agencies. Managers at the agencies differed in the amount of importance they placed on AMI's ability to capture interval data about water usage. At Suntown, senior managers' stronger emphasis on the data in part produced a more involved course of action that focused on who needed to work with whom. In contrast, Fogtown's senior managers were skeptical of the benefits of AMI data, which shaped a more process focused on efficient management of infrastructure assets.

Suntown: It's About the Data. Suntown's managers were excited about the potential for AMI's interval data output. They were not always sure how the data would be most useful, but they came to share a sense of its great potential. Dennis was a consultant hired by Suntown to help them prepare for, adopt, and implement an AMI system, and while working for Suntown he had many opportunities to see Suntown's workgroup talk about and work on AMI. He described how people at Suntown understood and therefore talked about the technology:

> Usually what I see is that most of AMI's potential gets left on the table. It's been misunderstood in the past that AMI basically is going to save money by keeping trucks from rolling down the street and reading meters. Troubleshooting, reading meters, making sure the data's correct—up until the last decade that has been all been done manually and is very expensive. What's being overlooked is the customer experience of being able to tell and analyze and forecast usage and demand and loads. And for utilities, assessing their distribution system and utilizing resources more efficiently. With AMI, utilities can provide financial incentives for individual account types that use either a lot of their product, or very little, or use it at certain times of the day that puts stress on their system. There's a whole bunch of analytics that go alongside an AMI system. Many of those don't get used to the fullest extent. [Suntown] doesn't have that problem—they get that AMI is bigger, and they see the value of the data.

Dennis emphasized that Suntown was not like other utilities who had more a limited view of what AMI could do. His experience with Suntown's AMI workgroup was that they saw the value of AMI's data to be useful beyond metering to areas of production, distribution, and more targeted water rate structures. This process began at the very beginning as the ad hoc group went through multiple trajectories of information seeking and action that produced more expansive and longer-term frames for the technology. The broad framing continued during the control phase as senior managers themselves adopted long-term and wide-ranging views of the technology and the data it would produce. Dennis made his observation based on his experience working with the Suntown group, and there were other examples that supported his perspective on the way in which senior managers talked about AMI.

One of David's catchphrases for the department was "building the trust and high regard of customers." He brought it up in almost every meeting related to AMI as a reminder of his and the department's customer-facing goals as an organization. The phrase became so familiar that staff referred to it as "David's trust and high regard emphasis," or called a customer-facing website about AMI the "trust and high regard webpage." During a customer service meeting when staff were sharing progress and soliciting input from David, he emphasized this goal in his comments:

> I take it back to an underlying principle which is our desire to build the high regard of our customers. We do that by having transparent data and making it easy [for customers] to access and understand their water usage… I want them not to be surprised and to be able to communicate with us early if they have a problem. This all goes back to the trust elements.

David's vision for AMI was a shift in how customers related to both their water and their water agency. He saw past the upgrade in infrastructure to the kinds of communication customers could have about water usage that would improve trust not only in the agency but in the City as a whole. For David, AMI was a tool to improve the City's relationship to the public. From there, he went further to see AMI as a way to deliver more targeted and relevant service to customers in the service rea. In this quote from an interview, David brainstormed some of the future applications of data from AMI:

> With this kind of data we know when people are home, when they are taking a shower. There are privacy and security issues there, but think about the data mining—I mean, the positive things that can be done with the data are pretty insane. There could be analysts where that's their new focus. They can be figuring out how do we take this data and how do we use it to have targeted messaging you know, rebates, things of that nature, that based on their certain behavior they may be most interested in.

David described a future of water management that was based in quotidian consumer behavior patterns that no other utilities were approaching at that time. While he did not have examples of other utilities adjusting rates or offering rebates based on customer behavior revealed through interval data, he imagined it was possible given the kind of data they would have access to with AMI. David's prediction for the potential of AMI data differed sharply from Fogtown managers' skepticism.

Fogtown: It's Not About the Data. At Fogtown, senior managers did not buy into the revolutionary potential for AMI's data output. They supported pursuing an AMI meter replacement program on the promise that it would homogenize their metering system and produce accurate reads for the entire service area. Lucille, filling as acting director for most of the year during which this phase occurred, described her understanding of the AMI project in an interview:

> Well, for me, the goal is to get 100% accurate readings across the board. Our meter stock is failing and we have to replace our meters. What else would you replace it with? You're probably going to do it with some kind of AMI system. But it's just not for water savings, I don't think. I try to talk with Conservation about what is the value then of AMI, and there's this thinking over there that people are going to be a lot more in control of their water use and all that. And I'm like, I don't know. Maybe. A lot of our customers don't care about that. For me when I see my water bill or examples of the data I'm just like, "I don't have time for this."

The director's understanding of the project was that it made sense to put in "some kind of AMI system" because that was what was becoming the standard in the industry. She saw her agency's problem as one of inaccuracy throughout the system that was causing problems in the meter-to-cash process and creating headaches for the metering and billing staff. Additionally, she was skeptical that customers would find much use in the data, as she herself was not even interested in what it could tell her about her own use. Hope, for whom

Lucille was standing in while Hope was Acting City Manager for six months, felt similarly about the usefulness of AMI data:

> I think that the challenge is to not get mesmerized by all this data and go into the glitz or the black hole of it all. Instead, we have to figure out what do we need data for? And how can we leverage the information into something that's useful for our planning purposes?

Hope's skepticism is clear, but it did not appear to drive her to answer the questions about leveraging data for planning purposes. Rather, the questions went unanswered and she remained skeptical about AMI's data throughout this period and beyond.

Lucille dismissed the idea that the value of AMI was in its improved data in part because the conservation group talked about it as a means to gain greater water savings. From Lucille's perspective, this made the data aspect of AMI less appealing because she and the other managers were planning on dissolving the conservation group. The City of Fogtown was in the unusual position of having successfully achieved their long-term conservation goals within the first few years of their conservation master plan. This meant that people within the division were adjusting to the state of "hardened demand." Demand hardening meant that people were already conserving as much as seemed both possible and desirable for the Water Division. As Lucille put it:

> With conservation, what is really the number below which people are not going to go? At this point it cost us more to conserve a gallon of water than it does to produce it. And at the end of the day, we are in the business of selling water. So we are bringing conservation along in that conversation, and then it's going to be a choice. If you don't like where we're at, you're just going to have to move on. Or you have a real passion for or belief system around conservation, and we can't provide that here, they can find a much more rewarding job someplace else.

Lucille's comments on conservation suggested that there was little room for dedicated conservation programming in the future. She intended to eliminate the conservation group and the majority of its programming because it was no longer needed. When changes in the organization took place that made people's positions redundant or unnecessary, management typically looked for another place in the organization to place people. Lucille suggested that if her staff in the conservation group insisted on working on conservation, they would have to go somewhere else. Evan, who was supervising conservation at the time, understood the predicament and did express hope that the organization would find a use for AMI data beyond metering:

> I think for Adam it goes back to the identity crisis that the conservation department is in. Adam really loves data. His faith in AMI is religious. He really wants the department to embrace the data and use it everywhere possible and then for him personally he wants a meaningful job in the department and he understands conservation is kind of done as a department. So he doesn't want to have a dumb job. He wants to have a meaningful job. He sees that our problem is more—at least with customers and rates—is affordability. I don't think he or any of us have any good idea of how to make the interval data serve that purpose.

Despite an attempt to find ways that AMI data might help customers save money on their increasingly expensive water bills, Evan and Adam were unable to find a way to get others excited about interval data. Thus, for management, AMI remained understood as a familiar operations and maintenance project that should be handled much like any other. After deciding what AMI really was, managers at both agencies turned to questions about how to incorporate the technology into their organizatoinal structure.

Questions for the Organization. When managers turned to questions of organizational control, they approached it in one of two ways. Suntown's senior managers were occupied with questions of division-wide reorganizing for OneWater, and thus were preoccupied by the question of who needed to work together. In a hierarchical organization like a municipal water agency, who worked with whom was largely dependent on department assignment. Instead of working across departments, people at Suntown tended to go through their supervisor when they needed information or action from someone in another department. Thus, the question of who worked together was essential for finding and enacting the right structure. At Fogtown, the question for organizing was one based in their understanding of AMI as technological substitution. Instead of asking about how people did and could work together, they asked what control needed to be executed in order to assure a smooth transition from one metering system to another.

Suntown: Organizational Change. To decide on a course of action, senior managers at Suntown focused their activity on the question of who would need to work together for AMI to succeed. They had learned both from consultants and from their outreach to other agencies that work practices would shift with AMI. They interviewed several colleagues from comparable agencies that had seen more success with broader applications of AMI data when they enabled closer coordination with people who used AMI. Instead of waiting for the technology to arrive, the management group wanted to take action in advance to align work practices with the AMI. They used their prediction of the future to inform a plan in which they would bring the present organization in line with their understanding of future events. By altering the organization in advance, they hoped to avoid a reactive chain of events later in which work practices and structure would adjust in response to AMI. David explained this approach in a meeting with Peggy and a consultant:

> We want to make the staffing changes in the next year so they are effective in that we can get staff on board where we want to steer them. We want this to happen in the not too distant future because we don’t want to have the system implemented and then start changes then. We’re familiar somewhat with what other utilities have done—we have studied the topic a bit.

George expressed his plans with confidence. Although he had not found examples of agencies that restructured their departments in advance of implementation, he described Suntown's plan to learn from the industry and try to get ahead of future events by starting the reorganization process early. George added to David's explanation by emphasizing that the existing needs of the organization needed to be met while they were changing in line with future needs:

> I need to make some staffing changes and I need to have a sense of what those are primarily related to AMI. So, I'm going to be wildly changing my business practices, implementing a new process is gonna be a new part of that. But after you implement AMI, there will be the new normal, so I'm trying to figure out what it is that my workforce needs to be. Cause in the meantime I still need to read 27,000 meters every month, but at the same time implementing this new software—it's integrated with our financing, with our billing, and so what is it at the end of the day that I need to do and how I communicate that to city council and water commission so that they understand what the plan is going forward

In explaining to staff what the reorganization would entail, David contextualized the change in light of which work practices were necessary both for AMI and for the OneWater program. He presented a list of "drivers for change," below in Figure 4.4, and talked through them in a large group meeting about the upcoming changes.

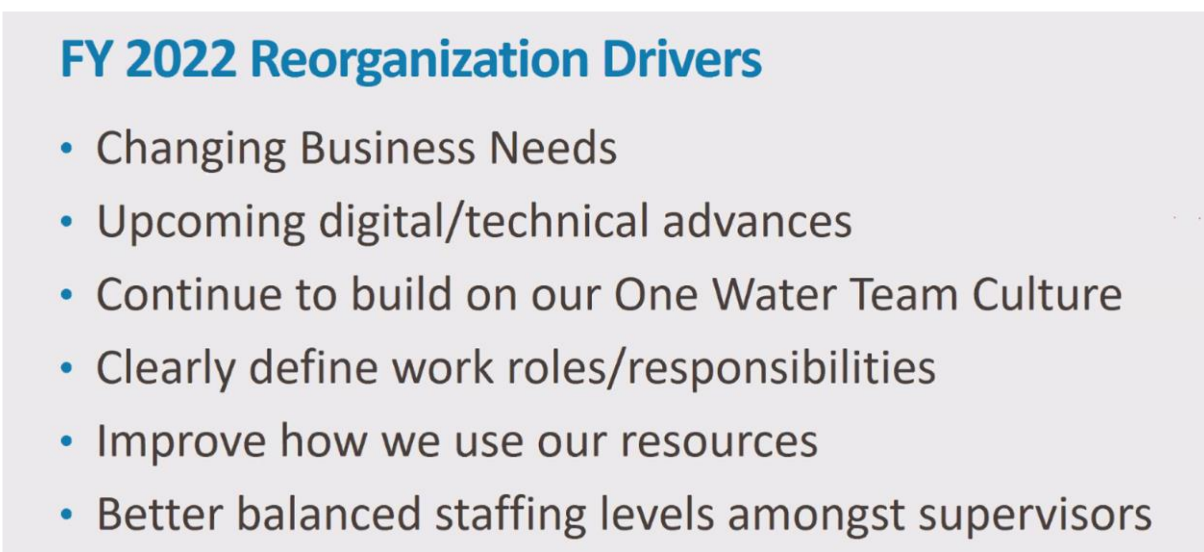


Figure 4.4. List of "Drivers for Charge."

In presenting the drivers to staff, David commented that AMI was not only a reason for change in the present, but also a driver of continuing change going forward:

> We're still making the effort and looking closely at the drivers for change and what we need to be focused on. We are an organization and community that embraces change and we structure ourselves accordingly. Our business needs are changing with digital and technical advances. Most notably AMI was a big project we've been working on, focused on, have a customer service steering committee heavily involved figuring out how that technology is going to reshape our organization. We continue to look at our changing business needs and there are other iterations of change coming in future years and we'll continue to embrace technology and be adaptive.

David encouraged his staff to think of organizational change as the new normal. He concluded his comments on the drivers of change by putting the transition in the context of OneWater and bringing people together in a more responsive way:

> As always another high priority is building our OneWater culture… We want workgroups that aren't siloes but support mechanisms to make sure we're responsive. We also want to improve how we use our resources—make sure we're efficient. Everyone is important in an organization this big with assets that stretch across mountains. With 130 people often times it's hard to make sure you're being resourceful and be efficient in delivering a service. The upcoming changes will make that more possible.

To achieve a "new normal" of continual change, David emphasized responsiveness in his comments. He and the other managers planned to make their staff more responsive by combining previously separate departments under a new superintendent position. Under the new organization, metering and conservation staff would be joined together into the same department. The proposed changes to existing positions were reclassifications that made water resource specialists "data analysts," and meter readers "meter technicians." As Renee put it, the restructuring would "even out the supervisory load of management staff across departments." Figures of the reorganization changes are in Figures 4.5 and 4.6 below.

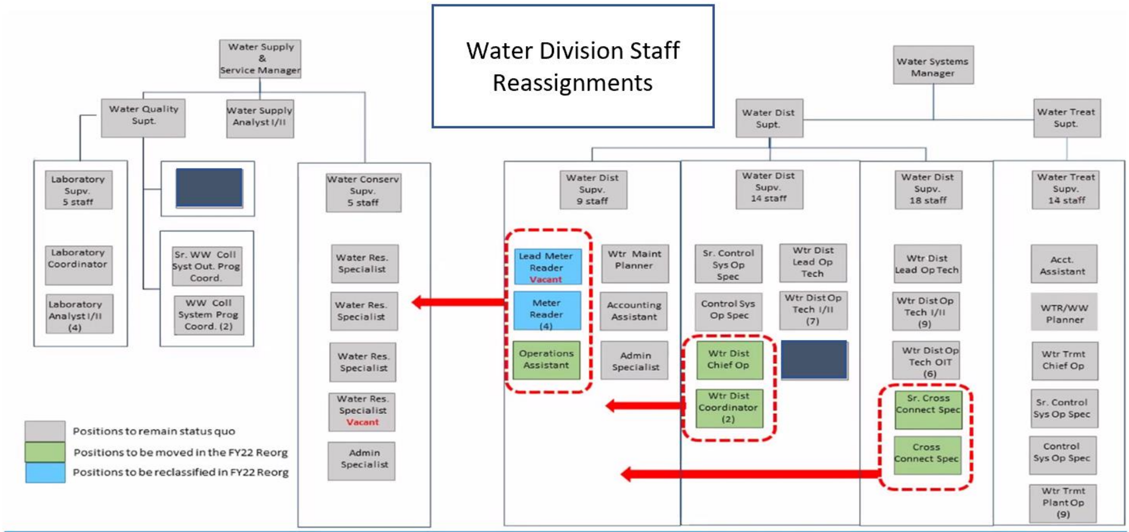


Figure 4.5. Water Sections Staff Reassignments.

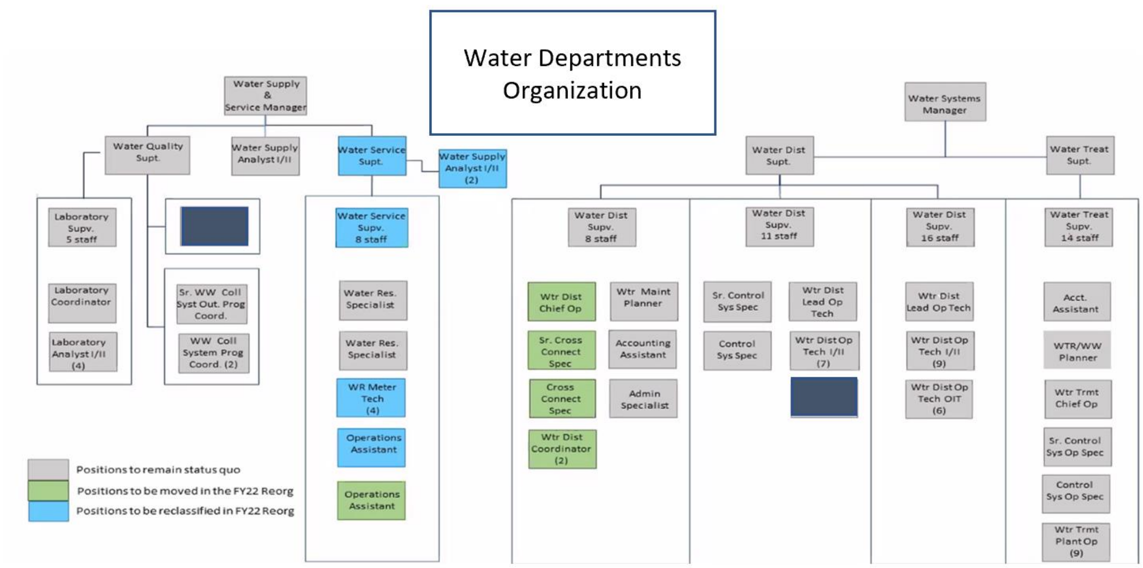


Figure 4.6. Water Departments Organization.

The structures depicted in the figures above represent the senior managers' plans for closer collaboration around AMI data in the future. The new organization put meter readers, newly classified as “meter technicians,” under the same supervisor as the newly classified “water supply analysts.” The purpose of this was to structure closer collaboration between the meter and conservation staff, who had up until now been physically and formally separated. The senior managers saw this as the structure most likely to engender experimentation, collaboration, and more efficient means of using AMI data to improve customer service and water supply management.

Fogtown: Infrastructural Change. Management at Fogtown understood the AMI project to be an infrastructure replacement project. Thus, their approach to change looked a lot like how other infrastructure work was done at the City. To get infrastructure replaced at Fogtown, it needed to be in a state of obvious disrepair before funds were approved and released, and no one fixed anything that was slated to be replaced unless it was absolutely necessary. Becky, a management analyst who worked on the AMI project under the direction of the director, explained the Fogtown approach to projects in an interview:

> We’ve always treated this kind of stuff as operation and maintenance because you just replace stuff when it’s totally broken. This is how [projects] get funded around here. You can’t get funding to replace a million dollar fire truck until your old million dollar fire truck is in pieces and broken down on the side of a road. I mean, that’s just how you get funding for stuff—only once its obvious that it has to be replaced.

Becky’s comment is helpful in explaining both how the AMI project finally got approved, and how the director then made related decisions about infrastructure spending ahead of the project. In Becky’s language, the meter system had become the proverbial fire truck in pieces and broken down on the side of the road. This meant that while the metering project had received funding after decision makers realized how badly it was needed, it also meant that it would be treated like a broken fire truck and left in disrepair until its replacement arrived.

Hope made decisions on her own because she did not always have confidence in the ability of her staff to make decisions that affected the department. Becky described Hope's approach to management and achieving uniformity in the meter system in the same interview:

> I think that was one of the things she identified right when she came in was just how incapable we were at at making decisions that wouldn't require, you know, business changes, operational changes. I think this group within the water department just really is not accepting of change. I really have an expectation that we're going to standardize on one system now. That like, we'll have the [Acme] system and everything will be that one technology. And then when that technology is outgrown, and we need to install new technology, you know, we can just do another just one new technology, we don't have to keep on. I mean we have five different systems right now or something. I got really frustrated, because the meter shop just did, they just ordered a bunch of old Sensus meters. It's like why did you order a bunch of Sensus meters? So frustrating to me, that, like, they just need to cut the cord and just go with one technology, you know, but they're just like, there's this... this hesitation for change, I guess, within this group, which is really interesting to me.

Where Becky saw a hesitancy to change, Hope saw a lack of respect for her authority. She described some members of the metering group as having "zero emotional intelligence" when they approached her in reaction to her decisions around AMI. She described one such encounter with Hunter:

> I remember having a conversation with Hunter, who came in here one day to tell me how wrong I was and asking why I was not supporting the work they were doing with AMI. You know it was fine that he came to see me. But finally I said to him at the end, you know I trust you to do your job, well how about you trust me to do mine? … I have worked in multiple water agencies I will tell you that technological change is a measure twice cut once kind of kind of thing.

Hope's description demonstrates a willingness to hear her staff's complaints, but also confidence in her ability to manage technological change. Rather than rushing to institute changes that people in the organization would come to regret ("measure twice cut once"), she took a more conservative and seemingly frugal approach to the change process: cut unnecessary spending given the coming upgrade.

How Does Reorganization Occur? The reorganization process at Suntown became official with a formal unveiling of the reorganization proposal approved by HR. This process was much more involved than the decision to cut meter repair budgets at Fogtown, which was an individual decision made unceremoniously by Hope. Thus, I do not explain Fogtown's enactment of control in this domain, as it was a declarative change made without processual complexity.

Suntown. At Suntown, action happened through the efforts of a closed group of senior managers. These included George, David, and Renee. Whereas earlier the three had solicited opinions and input from their staff, in the later stages of the change process this group worked secretively. Others did not know what they were organizing, but they knew they were working on something. Camilla described the opaque nature of the reorganization process in an interview:

> There's a "Super secret staffing plan." We all have a meeting on our calendar but no one knows what it is. Renee's going to have one on one meetings before or after. One of her main goals is rumor control, so all we know is that the meeting is happening... I know very little, but I am involved somehow. Something will be happening to me for sure.

Camilla described a secretive process that was intentional on the part of management. When the management group met to discuss plans for the reorganization, they closed their office doors and talked more quietly. When interviewed about the topic during this study, they almost always opted to meet at the end of the day when they could talk from the privacy of their home. Each of them increasingly emphasized the importance of keeping their comments secret as progress on the reorg advanced. To gain approval for a departmental reorganization, the group needed the blessing of the Human Resources department. The process of gaining approval was frustrating for the group. One reason for their frustration was that the group felt that they should be able to make changes within their own organization without having to convince human resources staff lower on the pay scale than them. As Renee explained in an interview:

> Basically all these changes are due to HR [Human Resources] at the end of the year. It’s all in the HR. Frankly, I don’t like how we have to deal with our HR. She’s one woman with 500 [municipal] staff to keep track of. We have to reorganize but parts of it she didn’t understand. But you know what, it’s a shame on her for not calling up and saying, Renee, I don’t understand what you’re trying to do here. She just denied it the first time we took this to her. Just flat out denied it. That was really frustrating because you know, you have George, David and me working on this and collectively our salaries are over half a million dollars. She makes around 80 grand, does not really understand our business, and is the ultimate decider. It makes no freaking sense.

Renee was clearly unhappy with the barriers HR put in front of her and other senior managers in attempting to gain approval for the reorg. Even though she wished it would go more smoothly, it was not altogether surprising that they were rejected on their first attempt. After all, this was by Renee’s own estimation the “first ever reorg on the basis of a future technology.” Thus, HR was not accustomed to this kind of feedforward control justified on the basis of a technology most people had never heard of. They needed more justification, and thus Renee and her colleagues had to try again in the next budget cycle. They needed to make a better case for why the change was necessary. To do this, the group wrote up a proposal and met with Human Resources several times to discuss it. The proposal included arguments for reclassifying existing employees and for moving employees to rebalance out supervisory responsibilities, which Renee explained in another interview:

> Usually, getting approval for a reorg in advance of the technology would be an impossible task. I made use of a “Writing A Problem Statement” exercise which we submitted to HR. I have used, and continue to use the “Writing A Problem Statement” exercise to make needed changes. I am hoping what I have written will help drive home my point, and this much needed change will actually happen.

Renee was aware that the justification for the reorganization was unusual, in that it was based on a coming technological change. She made the case for the changes using a familiar problem statement method. Excerpts from that problem statement are below:

> **Advanced Metering Infrastructure (AMI) Program**: A full-scale AMI program is funded for FY22. Successfully launching this program will require considerable effort, including new job duties and skillsets, to ensure there is no interruption with meter-data collection for the issuance of monthly water bills. Implementation of the AMI hardware/software, as well as the public outreach and education will be a significant new workload.
>
> **Type of problem**: Current employee classifications and practices need updating and realignment to meet modern business needs.
>
> **Cause of problem:** Customer expectations, optimization of staff resources, cost of water, water loss regulations and aging infrastructure are driving the need to modernize our business practices. Prior to FY21, Water Resources lacked a holistic customer service program. Our current staffing model is inadequate, and we need modern business tools such as AMI to meet customer service expectations.
>
> To best meet Water Resources' current and future needs by aligning programs with the appropriate staffing levels. This includes developing programs to improve customer service, address water loss in accordance with state regulations, and successfully transition to a citywide AMI system.

In the problem statement, Renee argued that the current classification and practices needed to be modernized. She provided a rationale related to customer service, as the municipal organization served its taxpayers and prioritized a productive and positive relationship with the community. Thus, to make their desired changes possible, the group worked secretly, pushed a series of justifications through HR, and based their justification both in the technology itself and the drive to improve customer service within the division.

Outcomes

Suntown. When presented with details of the reorganization, many of the affected staff were confused and dismayed. They reported feeling either that the reorganization was too early, or that it devalued the work of the conservation department. The meter readers expressed the former concern, while members of conservation expressed the latter. The major change for the meter readers was that that position of lead meter reader no longer existed. To successfully accomplish the high-paced work of capturing reads from the 27,000 accounts in the city, the group had always depended on the work of the lead meter reader. The lead meter reader assigned routes fairly among the group, processed data from the handheld devices that the group used to capture and transport volumetric data, and completed data verification and integration processes, and troubleshot any errors with colleagues in the billing group. The group, reclassified as meter technicians, would have to accomplish their work without a lead meter reader. Esteban, who was acting in the role of lead, commented on the reorganization in an interview:

> Personally I think it's two years too early. That's my big thing with it. They just have AMI on the brain! Probably because they're talking to vendors, you know what I mean? They're looking at AMI, they're doing a lot of like stuff. That's like AMI AMI AMI. I'm not involved with any of that. So for me, that's still like a ways away. I think I see why they're putting us with water conservation. Conservation is very customer orientated, and we can go out into the field and inspect things… And I'm sure they talked to other municipalities after they went to AMI, and we're just like, Hey, you know, what were the results of this? And I'm sure they were just like, you're gonna get a shit ton of phone calls.
>
> So I see that need. That being said, we have (whistles) zero AMIs in the ground! You know what I mean? And *if* everything goes according to track this is gonna be fully unrolled and implemented [two years from now]. That was the last update from Camilla, when she gave her a little presentation that I heard. I was like... Hey, why don't you wait until we have… I don't know, maybe at least *one* in the ground before we do this move? And it's just like, man, they're really banking hard on this happening? That's like my really big issue with this. It's just maybe not two years too early. But hey, maybe like a year too early? Like a year and a half too early. Why don't you just kind of at least wait until one of these test phases happens before we move everything around?

Esteban acknowledged the bigger issues related to his concern by pointing out that he understood why they were being moved into the conservation group. He had already begun to experience the uptick in phone calls from customers who were on the AMI pilot program, and he was not enthused about the prospect of having 20–30-minute-long phone calls with customers who were confused about what the new data were telling them about their water use. Even though he understood why the meter group was joining a more customer-service-focused part of the department, he felt strongly that the reorganization went through prematurely. Not only was his group still responsible for reading meters manually for at least another year, but his position as lead no longer existed. Esteban had been at the organization long enough to have seen other projects fall short of expectations, and he thought it would have been wiser to get some of the technology physically in place before restructuring.

Members of the conservation group took issue with both the demotion of their supervisor and the elimination of the word "conservation" from their titles. In an interview, Camilla described how Juliette's demotion sent the message that the City did not reward hard work:

> I feel like everyone has had a lot of feelings with the reorg. It was mostly what I expected for myself, but in general it was definitely not what I was expecting. I thought they were just going to take metering and plop them over into our group. I thought Juliette would stay the supervisor so I feel offended on behalf of that one. I feel like they screwed her over—like they full on demoted her. And it's sad, because it really just goes to show that HR is purely about protecting the business of the organization, and it's really not about how your employees are performing. And because Juliette is one of the top performers in the entire city, honestly. And she was the conservation supervisor through the worst drought we've ever seen and did really amazing things. It's just really sad. I felt really bad for her.

Camilla had been closely involved with the AMI project the past year and she was aware of the kinds of changes that were being discussed. It shocked her, however, that her supervisor, whom she respected and had had a positive experience reporting to, was demoted to an analyst. Juliette did not receive a cut in her pay or benefits, but with the restructuring she was no longer managing any of the conservation staff. She would have to leave her coveted office and relocate to a cubical. The transition was surprising to the group and met with dismay across the board. When asked her thoughts on the demotion, Juliette expressed disappointment but also understanding:

> I feel like it's still the changes are being made by people who don't have a lot of maybe insight or path, prior history of knowing what we do. So therefore it feels like I'm being devalued. It's not all negative… I do trust that they have done a lot of research and that they really feel like this is the best way forward. Also, everything always changes, like, I'm sure in two years, it'll be different. And then another five years will be completely different. At the City it's always changed around based on the whims of management. For me, though, I honestly feel like some more communication would have had it go better with the whole team. My sense is that it does feel like we're just changing the structure to set us up better for AMI, but there was no language about conservation or what we bring to the City in there.

In the interview it was the first time Juliette had been asked directly how she felt about her own position, and she fluctuated between trying to understand the intention of management, and feeling that they were out of touch with the important work she had supervised for so many years. Juliette was a detail-oriented and hard worker who was devoted to the mission of conservation. She was not inclined to promote her own successes, and some in the group felt this was one of the reasons her accomplishments had been overlooked. Juliette pointed out at the end of this interview that this was her dream job, and that she would "do it for free if I had to." Subsequently, she made an effort to accept the change graciously and help her staff take on the reorganization with a positive attitude. Camilla, however, had a harder time getting over what she felt was a blow to the conservation mission:

> What seemed what was happening to us is that Renee is a water distribution manager, and she's been in a water distribution her entire career and we just felt like she was just making all of us water distribution. She was homogenizing it. Everyone's water distribution now! We have felt like our identity was getting stripped, and they maybe weren't understanding how much conservation does. They didn't acknowledge the role of conservation in the reorg. They put our conservation specialists under the meter readers. It was kind of symbolic. I think they were kind of

> tone deaf on that. It feels like our group is being taken apart. To us it was like they were eliminating water conservation.

Camilla's comments mirrored Esteban's in that both felt like their group was being subsumed by the other. Esteban felt metering was "plopped" into conservation, while Camilla felt conservation was put "under" the meter readers. Thus, both felt like the reorganization shuffled them into a larger group where they would have to make do.

Fogtown. In contrast to Suntown's more time- and labor-intensive process around designing and strategizing a reorganization, people reacted to the one-off decision to cut meter repairs. Evan explained the decision to a colleague in a meeting:

> There was an internal decision to only replace meters if a customer calls in and self-reports that the meter is stuck. Because, you know, it just looks really bad if you don't take action when a customer tells you that there's a problem. But all the other ones that we discover ourselves or deduce that that are stuck, we're not running out to change those, because we're trying to, we're trying to hold back for the project for a couple of reasons. We want to keep the numbers as steady as possible right now. And then we also want to, we want to get the new pricing so we don't keep paying the street prices for the meters.

Evan described the decision from management as one that was intended to save money, but by his own calculations, the agency was losing almost $1 million a month in unbilled water consumption. This caused confusion and frustration among many of the workers out in the field.

From the perspective of meter technicians and other field workers, the shift to cut off funding for meter repair or replacement was sudden and confusing. All they were told was that there were to be no more repairs or replacements until the system-wide meter replacement was put out to bid and contracted out. No one in the meter shop was consulted on the course of action, and none in the shop understood or appreciated the abrupt change. Julian, a meter reader, explained the shift in their schedule in this way:

> Normally we get reads during the first two weeks of the month. The second half of the month we can’t get any reads because it’s out of the billing cycle. So we repair meters we flagged as broken. Now we can’t repair anything. I don’t really know what we’re supposed to do the second half of the month. I don’t even know what the other guys are doing. I try to find stuff to do or people to help out.

Normally, if a meter was broken and either not sending reads over the network or not registering water flow, field workers replaced it. Some of the meter readers felt like the City was throwing away money by not fixing meters. Martim, another meter reader, described his own frustration with the halt in repair work:

> Normally I’d replace the MXU because the meter was working. We’re making money out here! Just replace the MXU-! But no. this project came up all of a sudden and we can’t fix anything. All that money they could give everybody a raise…

As a meter reader, Martim was irritated that the City was giving away water for free. He saw every broken meter as a missed opportunity to collect revenue. As someone making less than the median income in the area, it seemed like the City did not care enough to collect revenue even when their staff were in much need of a raise. On one metering route, Martim came across a residential flower garden that was lush and full of blooms. He pointed to the garden and said, “You know what? They aren’t paying for any of that. I’m not even going to check the meter because I know it’s broken, and so do they.” See a picture of that garden below.

Figure 4.7. Residential Flower Garden.

Lots like this stood out among the sparse, drought-tolerant landscapes that many Fogtown residents had transitioned to after reoccurring instances of water shortages. Martim was not the only one who noticed how some residents were taking advantage of knowledge that the meter stock was failing. Evan told a story during a meeting about news of the broken meters reaching the director:

> Yeah, there are plenty of people. I mean, I, you know, there's, there's people who call and tell us, hey, I looked at my bill and I'm not getting charged for water and you know, okay, thank you very much the issue is that we don't have meter stock right now to run out and replace those. Someone even contacted Hope directly, and said, hey, I was at a dinner party and a friend of mine told a story about how they called the customer service office, because they had noticed that they hadn't been charged for water for a couple of months. And the customer service office said, oh yeah, you got a stuck meter, don't worry about it. We're not doing anything about that. There's going to be a big project coming up, and you'll get a new meter eventually. And don't worry about it, you're not going to get back billed. And so the customer wrote to Hope to say what gives? And, you know, Hope kind of punted that to me and I had the reply to the customer.

As Evan reported, news of the extent of the meter crisis had begun to spread among the service area. Hope, but also City Council members were beginning to be contacted by customers who were concerned that people were not being charged for their water use. At the time of Evan's comments above, the city had announced a Stage 1[8] drought declaration, which meant customers were receiving guidance about conservation and future penalties for overuse in the case of progression to Stage 2. The pressure on customers to conserve conflicted with the growing awareness that others were not being charged, and this created a delicate problem for customer service staff. All of this served to fan the flames of discontent

[8] Drought management took place in progressive stages. Early stages advised residents to voluntarily reduce water consumption, while later stages required reductions and issued fines for noncompliance.

among staff at Fogtown as they worked to maintain the failing system and looked to the promise of a future, uniform system just around the corner.

Conclusion

Already at both agencies, much had changed in anticipation of AMI. Anticipatory control brought about the most consequential changes so far. At Fogtown, members of the public were beginning to complain about the state of the metering system during a time of drought, and workers throughout the division felt frustrated with the directors' decision making that exacerbated problems related to aging metering infrastructure. At Suntown, staff were presented with major organizational change in the form of a "secret staffing plan" that caused frustration and confusion among the conservation and metering staff, both of whom felt misunderstood and unappreciated in the departmental reorganization. The nature and consequences of change during this period can be explained by executive action. Here, executive action consisted first of developing surrogate time models that encompassed the coming technology within the context of the entire organization, and related actions of feedforward control to align the organization's present state with future needs.

Organizational change at Suntown and infrastructural change at Fogtown occurred within a two-phased period of anticipatory control by senior management. With an eye towards their organizations' futures, directors at both agencies took it upon themselves to align the agencies with the future they saw as most probable. They were influenced in their understanding of AMI during the first phase by the ways in which their staff talked about, positioned, and championed the technologies. In the second phase, directors decided and implemented a course of action. At Suntown, they emphasized AMI's massive data output and asked questions about what preparation was needed to best take advantage of the new source of data about customer water use. In contrast, at Fogtown, the directors were skeptical about the promises of the data and thus were not motivated to ask the same kinds of questions about staff collaboration and organization as their counterparts at Suntown.

After the anticipatory changes explained in this chapter on control and the previous chapter on the early days of AMI, finally both agencies arrived at the time for technology selection. The most important outcome of anticipatory control for the subsequent process of selection was that Suntown was primed to account for recent organizational changes in their selection process, while Fogtown faced the pressure to quickly replace an even more rapidly declining metering system. This and the preceding chapter have shown that selection is far from the beginning of the technologically induced organization change process. The experiences of Suntown and Fogtown demonstrate that a great deal of sensemaking, decision making, and action took place in the name of the coming technological change in the years leading up to selection. The selectors came to the table having been shaped by their experiences thus far, and in light of the organizational changes underfoot, whether they were in the form of rapid infrastructural decay or major departmental reorganization. They looked to the selection process to choose the technologies that would best serve the organizations they were at the time, and the organizations they would become in the future.

V. Anticipation and Materiality: Selecting Digital Technologies

It had seemed to some at both agencies that AMI might never arrive. Long-time meter readers joked about how many more decades it might actually take, doubting whether their agencies could accomplish the shift to AMI. Finally, however, both agencies initiated their formal selection processes, or as it is called in government, they began "procurement." People at both agencies gathered the knowledge and experience they had gained in the preceding years to begin the long and technical process of selecting the components of their AMI systems. Before selection AMI had always existed as a possibility but was not yet a reality. People had ideas about what they wanted the systems to do, but they had not encountered or discussed the system's more technical features. In the previous chapters we have seen how the anticipatory processes of each agency shared many comparable features. During initiation, both groups progressed through trajectories of information seeking and action to develop shared predictive frames of the technology. Through anticipatory control, people at both agencies influenced executive action through their use of language, the way in which they positioned the technology in relation to organizational strategic planning, and the nature of the role of technology champion. In this chapter I explain how activity before procurement shaped the process of selection and the materiality of the systems they selected. Each agency took categorically different approaches in their procurement processes.

Years of technological anticipation at both agencies produced the conditions of selection. At Suntown predictive frames and organizational changes shaped what technology was selected and what its integration between components and systems looked like. Fogtown's previous anticipatory organizing limited the options that the organization had for procuring the technology. Senior managers were not enthusiastic about the technology beyond its function as a meter replacement, only a small group was involved with supporting the technology, and many suffered from low morale about the potential for success. Thus, the primary impact at Fogtown was processual. Fogtown organized an unorthodox process to simplify procurement and reduce opportunities for others to block their progress. Their approach greatly limited their choices in components, which meant that Fogtown had little to no ability to choose among technologies and shape material outcomes.

While both agencies eventually selected an AMI system after a group worked together to navigate municipal procurement requirements, beyond these two factors very little was similar between Fogtown and Suntown. The procurement structures they used and the way in which they selected each AMI component differed so significantly that in this chapter I separate the processes into two parts. The first part recounts Suntown's procurement process and the way in which it shaped the materiality of their digital system, and the second part explains how the processual outcomes of Fogtown's anticipatory organizing limited the agency's technical options in procurement.

Part I
Antecedents of Implementation and Use's Implications for Materiality During Selection at Suntown

Students of technologically induced organizational change have asked how the structure of an organization can shape the change process and its outcomes for the organization and the people who work there (Bala & Venkatesh, 2013; Orlikowski, 2007; Vaast & Walsham, 2005). Research following this line of inquiry has assessed the relative impacts in two ways. On one hand, technological change affects the structures, and social processes of organizing. Studies in the social sciences that report organizational impacts extend back for decades and have found that the adoption of new technologies can shape almost every aspect of organizing, including routines (Edmondson et al., 2001; Orlikowski, 1996), occupational positions of power (Braverman, 1998; Faraj et al., 2018; Marx, 1867; Noble, 1979), knowledge (Anthony, 2021; Roy & Sarkar, 2016), and learning (Beane, 2019). Chapters 4 and 5 contribute to this stream of research in assessing how predictive technological frames and anticipatory control shape the social practices of information gathering, predictions, and organizational action. I turn in this chapter to the questions of the material and processual impacts of anticipation in asking how anticipatory organizing shapes technological systems during the process of selection.

Beginning in earnest in the late 1970s, scholars of the Social Construction of Technology (SCOT) reversed the dominant direction of inquiry to ask not how the technological affected the social, but how the social affects the technological (Bijker, 1995; Pinch & Bijker, 1984). Looking to examples of everyday artifacts like bicycles and fluorescent lightbulbs, SCOT theorists identified the importance of *relevant social groups* to the design process. In part as a function of the *interpretive flexibility* of artifacts, social groups that used early forms of technologies were found to develop a shared sense of meaning about what an artifact was and how it could and should be used. SCOT scholars explained how these social groups influenced the design of technologies, such that they reached a state of eventual *closure* after which their design ceased to evolve and change. The most famous example in this tradition is the impact of social groups on the design of "safety bicycles" and their component parts, including the type of drive train, size of wheels, and shape of the frame. The interpretations groups shared (i.e., whether bicycles were meant for speeding dangerously down steep hills or riding calmly along a flat promenade) were a consequence of their users' everyday activities, position, and access in society. For scholars asking how social forces shape technologies, the SCOT tradition facilitated a turn from analyses of the designers and manufacturers of technologies to the users of technology, such as the laborers, factory owners, homeworkers, and consumers. It was through the SCOT framework that scholars could rediscover the important role of users in the history technology.

Scholars of organizations have since enriched our understanding of how social practices can and do shape material technologies. A greater focus on material outcomes was needed, Leonardi (2009) surmised, because in most studies of technological change the focus is on change that occurs during implementation and use phases,

> …the physical features of a technological artifact … are usually considered stable and unproblematic while the perceptions, appropriations, and interactions that individuals generate in response to that technology are seen to evolve and change over time. (p. 292)

It is clear that technologies' physical features do in fact change through implementation and use. Barret et al. (2012) demonstrated this in their examination of the emergent and iterative change process of a pharmaceutical-dispensing robot, which was used and depended on by three different occupational groups in an organization. Problems with the robot's original configuration triggered a period of accommodation and material adjustment. The robot's first installation irritated many of its users as it caused the assistants' workspace to become cramped, crowded, and less desirable, and additionally caused conflict between front- and back-end dispensary work due to an unsuitable and error-prone automated dispensing procedure. Over time, users reconfigured the structure and boundaries of the robot to accommodate each of the three occupational groups' needs. The means by which actors create meaning and interpretation through sensemaking have emerged in the literature as important forces of material change (Orlikowski & Gash, 1994; Walsham, 1995; Weick et al., 2005). Longitudinal studies in particular that have been able to track users' interactions, shifting structures, and interpretations as they adapt to a new information system have shown related changes in information system architecture (Majchrzak et al., 2000; Treem & Leonardi, 2013).

Social processes and material technologies mutually constitute one another. Studies of sociomateriality have analyzed the work practices of users of new technologies to show how the material and discursive are inherently inseparable (Leonardi & Barley, 2010; Orlikowski & Scott, 2008). It is important to understand how anticipation shapes later processes because, as Leonardi (2012) has argued, sociomaterial practices do not occur free from a historical context of past sociomaterial practices. In their research designs, scholars have looked almost exclusively at implementation and post-adoption use for evidence of practices that shape social processes and materiality (Jasperson et al., 2005). Studies of technological frames (Azad & Faraj, 2008; Davidson, 2002; Gash, 1992) and users' perceptions of a new technology (Rindova & Petkova, 2007; Zunino et al., 2019) have explained differences in how the same or similar technologies can be understood and therefore used in such different ways once actors gain access to the material artifact. New research suggests that users' activities *before* access to the technologies can affect the processes in organizations and the materiality of the technologies they use through other means. For example, differences in firms' adaptative capacity for technological change exist "well before change occurs" and are important levers during selection and implementation (Aggarwal et al., 2017, p. 1212). Rumors in the media about forthcoming products, for example, function as a "prehistory frame" that recursively influences producers' "opening up or narrowing down" of options in the late stages of the design process (Seidel et al., 2020). Seidel and colleagues found that rumors of upcoming products that circulate on tech blogs, social media platforms, and traditional news outlets can criticize or celebrate a particular function of the new iPhone. Designers react to the buzz created by the rumor either by expanding options to better capture the public's enthusiasm, or by narrowing options to background facets of which commentators are critical. Rumors are just one potential organizational activity that can shape materiality that does not depend on user interaction. In this chapter, I ask how anticipation shapes both the *process* of selection and the *materiality* of the technologies chosen through the selection process

For Suntown's selection process I explain how anticipatory organizing shaped both the procurement process and the many choices available to the agency regarding the materiality of the technological system they organized to select. The period I analyze in this study is between the two organizational stages of selection, which Thomas (1994) called selection *between* technologies and selection *among* technologies. We have seen thus far how Suntown began organizing in anticipation of AMI, which started with their selecting between multiple options, such as staying with mechanical metering or adopting a drive-by AMR system. Through procurement, Suntown selected a system among a field of AMI technologies based on technical specifications developed in advance of the procurement process. In what follows, I explain how Suntown's departmental reorganization and associated changes materially affected the selection process and eventual AMI system adopted by the agency.

Process and Materiality in Anticipatory Selection

Suntown's procurement process was managed by a group of selectors. Selectors were a group of 10 representatives from metering, distribution, billing, conservation, and IT who were asked by senior managers to participate in the selection process. They produced and published bid documents for the AMI system, read and scored the responses, interviewed a short list of candidates, and awarded and negotiated the final contract. The selectors expanded on members of the ad hoc AMI working group to include additional representatives from billing, IT, and senior management who had so far been involved in the AMI process sporadically or from a distance. Selectors organized procurement into two phases: technical specification within the Request for Proposals (RFP) that the agency publicly distributed for responses from vendors and the scoring of proposals. With the help of their consultants, selectors produced a list of 390 technical specifications that they ranked as "nice to have," "important," or "critical." To decide on specifications and assign ranks, selectors worked over a series of meetings with their consultants. Consultants provided a draft list and facilitated a discussion of the range of capabilities of each and every technical component. For example, for the customer portal they categorized "allow customer service representative to sign up a customer on their behalf" as "critical," "include native mobile application" as "important," and "support comparison of customer's current usage to a monthly budget for irrigation" as "nice to have." For the Meter Data Management System, they categorized "provide reports that compare multi years (>2) of historical data side by side" as "critical," while "render meter records on a map view based on report results" was only "important."

Consultants helped by explaining what each potential technical feature was and why it might be important to the City. The selectors then discussed the implications of that component and gave it a ranking. For example, in what was a typical conversation around one component, the group discussed how to rank battery and solar power requirements for the data collector units:

> Manual: I want [the consultant's] opinion on this solar versus battery thing. The city is into green things, but I'm not sure we'll get a lot of value for it if we require it because we'd be paying for both direct power and solar power essentially.
>
> Consultant: Even with a utility connection to the units you're gonna want a battery backup.
>
> Manuel: So even with utility power you want a battery system?
>
> Consultant: Oh absolutely. Normally you want city power connected to it, but then you have to think about how reliable is the power, what outages do you have, what level of redundancy is in the system. If the collector is down x number of hours does it really matter or not. The battery is really common as a backup, but the battery is a weak link because you have to replace it every five or eight years. It's the same battery technology you'd have in a laptop or cell phone. After three or four years your cellphone battery isn't that great.
>
> Manuel: Peggy, I've seen that our power in Suntown is pretty reliable, when there have been fluctuations it's for a short time. I've seen generator turn on at public works for four hours max. So I'm thinking we go with battery as "critical," and solar as "nice to have." Solar is the lower priority.

The three-level ranking system helped the group prioritize technical components. They did not want to mistakenly require something as "critical" that was not necessary and would limit their choices from among the firms that responded. For example, if they decided to list both solar and battery backup as critical, some firms would be unable to deliver and be scored lower as a consequence of their inability to meet a "critical" requirement. In the proposals firms could not provide a "critical" component, were asked to clarify in writing whether the component was something they would provide in the future as part of their base package (called "future base") or whether it was possible to customize the technology to meet the

City's requirement. Scoring involved the assessment of both the submitted written responses and subsequent interviews from shortlisted candidates. The scoring process combined with shortlist interviews informed the group's decision for the final award of the AMI contract. Selectors saw the process of writing the RFP as a means to get the system they most wanted. Peggy and Juliette talked about their hopes for the procurement process in a conversation before a weekly status meeting started:

> Peggy: The things we want to get out of the system are things like using the data internally, tracking meter functionality, the overall asset management of the meter system... I think what we've learned so far from our pilots and the research and site visits is that this process is for making sure we have the features we want. We need to make sure we have enough weight to be able to exclude someone who doesn't have those features. Would you agree?
>
> Juliette: Yeah. Sometimes it's gonna be hard to determine because they will be good at sales pitches during the RFP presentations, but we've learned a lot from our pilots. We'll have to see through some of the BS.

Juliette expressed confidence in their ability to "see through some of the BS" during the sales pitches on the basis of their research and experience so far. This conversation demonstrates their hope that specifying technical requirements for the AMI system through the RFP would enable them to exclude applicants on the basis of their system functionality. Public officials like Peggy and Juliette were accustomed to optimistic sales pitches from hopeful vendors and they steeled themselves for the process ahead.

Anticipatory organizational change influenced Suntown's identification of technical requirements. While the reorganization developed by senior management had not yet taken effect when procurement began, its core features were known and present in the selectors' discussions and decisions. There were three structural changes and related organizational factors that influenced corresponding technical requirements. These were *job reclassification* for the hiring of data analysts, *reorganization of metering and conservation in a new department* and a *new interdepartmental customer service working group*. Each of these and their related technical specifications are below in Table 4.1:

Table 4.1

Organizational Considerations and Technical Specifications During AMI Selection

Structural change	Organizational consideration	Technical specification	Chosen technical features
Job reclassification *New job descriptions become more technical* • Conservation specialists become data analysts • Meter readers become meter technicians	**Metering and conservation work becomes more data driven** • Customized data analytics	AMI data must be transparent and fully accessible	Non-proprietary database file structure that was ODBC-compliant and SQL-compliant, and provided by standard database supplier
Reorganization of metering and conservation in new department *Two groups now report to one manager* • Integrated expertise should solve problems faster • Mandate reducing field visits	**New group will solve more complex problems from office remotely** • Reduced truck rolls • Customers will not be transferred between departments	Network that allows for near real-time data pings to meter for updated volumetric reads	Two-way network communication 15-minute pings to meter for volumetric reads
New interdepartmental customer service working group *Technical working group expanded to include members from other departments* • Group's focus is changed from AMI to customer service. • Members will share learnings from AMI data and suggest ways to improve work with new reporting and analysis • Customer service encompasses both external water customers and Water Division itself (i.e., work orders, repairs to internal infrastructure)	**All departments need to generate insights about data** • Information exchanged across groups	• Ability to integrate with existing systems • "Turnkey" implementation proposal • User-specific landing pages	MultiSpeak programming standard

Each organizational change, whether already or imminently enacted, had a corresponding technical specification. This meant that the material system chosen by the selectors was directly influenced by organizational changes made in anticipation of the technologies they were now poised to adopt. The experience of reorganization, however, taught those affected by it more about what work would look like with the transition to AMI, and thus informed their desires for the technical system itself.

Job Reclassification

Structural Change. Senior managers reclassified several positions within the Water Division. To take advantage of the new system they intended to either retrain or hire people with more advanced data analysis skills to fill new positions within the department. Meter readers were upgraded to "Meter Technician I" and "Meter Technician II." Once the system was installed, meter technicians were expected to do more work from a computer in the office and engage with the meter data management system to manage meters remotely whenever possible and use data to diagnose and fix problems. The Water Resource Specialist was reclassified as an analyst position. The old and new job descriptions are below in Table 4.2.

Table 4.2

Job Descriptions of Reclassified Positions

Old position	New position
Meter Reader: This position requires reading water meters and recording consumption; identifying water meter equipment problems; notifying customers of account discrepancies; discontinuing customer service. Field environment includes exposure to dust, noise and inclement weather conditions; may be exposed to domestic animals and insects. May require maintaining physical condition necessary for walking, standing, bending, stooping, kneeling, crawling for prolonged periods of time; may require lifting up to 50 pounds.	**Meter Technician:** This position assists with the operating and maintaining the Advanced Metering Infrastructure (AMI) system, including water meters, AMI hardware, and associated equipment; troubleshoots mechanical and electrical equipment and system problems; responds to customer service calls and work orders; provides customer service for meter-related and private water-use issues. This position also provides public information on water use, water conservation, water quality, and water supplies; assists water operations staff with troubleshooting problems where public and private water systems interface.
Water Resource Specialist: To implement water programs and assist in the management of the City's water supplies and/or water distribution projects within the Water Resources Division; and to develop and implement storm water and urban runoff water quality improvement programs within the Creeks Restoration and Water Quality Division; enforce storm water regulations; and to perform a variety of technical tasks relative to assigned area of responsibility.	**Water Supply Analyst:** To perform a wide variety of administrative and analytical duties for an assigned department; to participate in administrative processes, procedures and programs; and to provide information and assistance to the public regarding assigned programs and services. Incumbents of this professional series perform increasingly difficult and complex administrative analysis tasks, conduct management studies, and coordinate projects.

There were consequential differences in the shift from the old to the new job classifications for the metering group. Both workers and managers at Suntown saw the structural change as a catalyst for shifting organizational considerations. The reclassification represented the greatest change for the meter readers. Three of the five meter reading staff were nearing retirement, and none of the three older men intended to stick around for the transition to the new role. Arnoldo was not planning on fulfilling the advanced technical requirements of the new technician position. One explanation for Arnoldo's relaxed attitude about retirement and technological change at work was that the meter readers had been repeatedly ensured that they would not be let go once the AMI system was in place. Managers talked about the kind of work they predicted meter readers would do once AMI was involved, and often reminded them that no other agencies reported layoffs as a consequence of AMI. For the older meter readers like Arnoldo, however, the technological change aligned with their plans to retire. Arnoldo talked about the changes afoot while driving around the City to verify meters that had high reads for the billing cycle a year before AMI installation:

Arnoldo: Bill has been here forever. Javier is actually talking about retiring too. I figure if I can get away with getting out of here, cool. I've got other activities I can fill my time with. I'll do whatever is needed while I'm here, but us old guys have a hard time with the computer work.

Interviewer: You're close to retirement?

Arnoldo: Yeah. I'm excited. I'll ride my motorcycle up and down the coast more! I think I'll still... I'll probably look for a little part-time job. Just makes things easier financially. But I feel real blessed that I can actually talk retirement at all.

For decades meter readers like Arnoldo had spent the entirety of their workday alone in the field and away from the office. The new classification required metering staff to spend most of their time in the office at a computer or on the phone. Arnoldo did not even use a computer in his work now, and it would be difficult for him to transition to the new system. For the new meter technician role, management expected the group to do one or two physical visits to the meter in a given year, but largely anticipated that the change would be a significant reduction in field work.

The description of now obsolete meter readers in Table 4.2 was of a blue-collar field job. Meter readers' primary responsibility had been to collect data from analog equipment. In the past, they needed to know the physical equipment well enough to identify, diagnose, and report problems to customers and their supervisor. The City advised potential applicants to the old position that field work was unpredictable and physical, and that they would need to be able to crawl, access small spaces, and lift at least fifty pounds. In the pre-AMI organization, on daily routes meter readers often encountered bad drivers, spiders, snakes, and aggressive dogs. With the structural change, any descriptions of fieldwork and physical labor were noticeably absent from the new Meter Technicians' job. Instead of gathering data, meter technicians analyzed and acted on the data from the AMI system. They were expected to spend time on the phone with customers, "provide public data on water use," and troubleshoot a variety of system interfaces. The shift from Water Resource Specialist to Water Supply Analyst also represented a similar advancement in technical responsibilities. For example, instead of "implementing programs," analysts would instead "perform increasingly difficult and complex administrative analysis tasks." The bar on technical engagement was raised for both positions.

Selectors often talked about the reclassifications and other structural changes during procurement meetings. It would take time for the changes to be finalized and filled, but many already had a vision for what work would look like in the coming year with the changes. Peggy described her hopes for the new positions in a conversation with one of the consultants during an RFP preparation meeting:

> We've seen two sides to the analyst role, as far as its being one that is more computer based and more technical. They should be maintaining the MTU programing software, responding to system integration errors, looking at all of these communication issues on the City side. Then on the customer facing side, they should

> be someone who is monitoring the system for spikes in customer usage. We might want to reach out to the customer. There is also the bigger picture of what our overall demand trends are, a water loss analysis, things like that. From what I'm hearing is that the analyst could cover both of those things. With two analysts there would be a lead tech role that would be able to help with the heavy lifting, actually doing programming and more computer related stuff versus the data analysis stuff.

Peggy talked about the structural change as one where the new analysts would work closely with the data and technology. She envisioned one person doing the "heavy lifting" by programming, writing code, and producing reports, while another could be responsible for analysis to track system health, water loss, and customer usage spikes. Allen, the consultant in the meeting, agreed with Peggy and extended her description to a closer collaboration with the City's IT department:

> This is someone who will get into the advanced reporting, depending on what MDMS you end up with. They are someone who needs to be proficient in software, understand reporting, and depending on how much you guys want to get into analytics, they are the person who works with your IT people. They take that data and become the interface between management and the IT side of things, so to speak, because your analyst is more of a build out kind of person.

Allen's comments described how the analyst could improve the relationship between management and IT by building out reporting and analytics within the MDMS to support organizational goals. Suntown wanted the system they selected to work for them, rather than having to adjust to its technical limitations and structural features. They wanted analysts on staff to use it as a tool to advance future organizational goals. Of course, Allen reminded the group that much depended on "what MDMS you end up with." Thus, the task for selection was to select an MDMS that would support their goals for the advanced technical abilities in the new positions and reclassifications.

Technical Specification. Suntown selectors were clear in their intention for the analysts to access raw AMI data to produce custom reporting. They did not yet know exactly what reporting or data applications they would use, but they did know that they needed full and transparent data from the AMI system. To this end, they specified database access as a "critical" component in the RFP technical appendices. In reviewing the proposals from contractors, they were surprised that one of the highly respected firms did not allow full access to the database, despite their indication of it as critical system element. The group discussed the response during a technical review meeting with Dennis from the consulting team. The meeting took place on an online meeting platform, and while they talked Dennis shared a spreadsheet of the technical requirements response from one of the contractors on the screen. Dennis facilitated the scoring meeting and called the group's attention to a line on the spreadsheet with the requirement to "have a non-proprietary database file structure that is ODBC-compliant and SQL-compliant, and provided by standard database supplier." This requirement asked specifically for the database to be "[Structured Query Language] SQL-compliant," which means that analysts could use a standardized programming language to access the database for purposes of managing and performing operations on it. They additionally specified Open Database Connectivity (ODBC). ODBC is a Microsoft programming language interface that allows data access to applications from a range of database management systems. ODBC is designed so that databases can connect more easily. Both SQL and ODBC compliance were specifications that would allow for ease of access to data from the AMI system and the potential for City programmers to build out reporting as needed.

The contractor responded that this was not provided. They did not use the comment section of the appendix to explain why this was the case. Peggy and Manuel took issue with the shortcoming during their review, and Mitchel from IT added his own thoughts:

Dennis: This contractor indicated “Database access is not provided.” This seems like it’s critical.

Peggy: Not even any comments from the contractor about that?

Dennis: (highlights column G on spreadsheet). Ok so item 6 in column G… they are saying no one has access to their AMI database. In the RFP we are asking for a non-proprietary file structure where we can do SQL queries, but they do not provide that.

Mitchel: That’s a bummer. And what would happen is if you don’t get access to database, you are stuck with any reports they have. But if you want a special report in real time, you are not gonna get it if they don’t let you into the database itself. We had that problem with the land use software. When City users go to cloud, it’s an add on to get real-time database access. Other than that you only get it every quarter, which is worthless.

Dennis: Some of these vendors will provide a staging database that they replicate, not the production database, but a staging database

Manuel: What actual info is in this database?

Mitchel: Dennis would know better.

Dennis: All the meter reads, all the meter data, serial numbers, everything associated with that that the endpoints have available to publish. Sometimes they will provide a tool to archive. If we want to build our own ad hoc reports, like some in house customer reports developed by us, then having access to that data is pretty critical.

The group agreed with Mitchel that the limitation was a “bummer.” They had designated database access as a critical component of the RFP, and thus deducted points from the contractor’s proposal. Unless the contractor could demonstrate a willingness to adjust their database policies, their lacking this component presented a significant disadvantage for their bid. The selectors made a note to ask if the firm provided any other access configurations, but ultimately did not select the contractor for a shortlist interview.

Reorganization of Metering and Conservation into New Department

Structural Change. Many pinned their hopes for AMI on the creation of a new department. Organized under the supply side of the Water Division, the new department was home to the newly reclassified positions and was headed up by new superintendent and supervisor positions. The changes represented a variety of opportunities to many in the Water Division. The creation of new management positions was a rare event at the City, and some saw it as a new opportunity to move up in their career. Others saw it as a chance to move laterally and get involved with something new. The primary intention of the reorganization, however, was to better facilitate use of the AMI system for the improvement of customer service. By combining the reclassified meter technicians, data analysts, and conservation staff into one department, senior management hoped they would collaborate and find greater use for and efficiency gains from AMI data. Renee described the structural change during the meeting with almost 100 Water Division members:

> The new department will be a powerhouse for planning projects, overseeing projects, private and public, and coordinating projects. It'll be an impressive group. Under the new water service superintendent it will be a powerhouse for customer service. The meter readers, working with the water service specialists, and a dedicated superintendent, it'll be a powerhouse group. We're really pleased.

Renee's comments evinced confidence and enthusiasm for the new department, but what did she mean by a "powerhouse for customer service"? The power was largely to be found in the advantages of closer coordination between staff. By putting conservation workers who understood how to recognize and address customer leaks together with the metering staff who knew the city and the metering system inside and out, Renee and her colleagues felt they had a created the structure for a dynamic, data-driven grouping within the Water Division.

Almost everyone agreed that work was about to look very different in this new department. Dan, a technical consultant brought in to help build the RFP, summarized the changes ahead. He described a day-to-day scenario of largely remote AMI-based customer service work for the meter technicians during a meeting with the City:

> One person is going to run daily desktop exercises. When their day starts and they come in, pull up dashboards, look at making sure all the network is up and running. If it's not, then resolving any issues that may have occurred. More common is going in and identifying meters that haven't been communicating. Maybe the meters have aged, or are having other problems, and then within the group, people are correlating meter issues to the billing cycle. Like if cycle 1 is coming up for billing, they are looking at any meters in cycle 1 that haven't communicated for a period of time. They do something in the back office to get communications to happen and if they don't, then somebody needs to go out and investigate the meters that aren't communicating. That's a day in the life.

Dan's description indicated daily interactions with a variety of data and reporting functions. The Suntown team was eager to ensure that the kind of day-in-the-life that Dan described was technically feasible. This meant that they had to specify a series of technical requirements for bidders so that when they selected among technologies on offer, they would get the system that could perform in the way they planned.

Technical Specification. Selectors were clear about how customer service was changing in the new department, but they had seen enough systems to understand that they would need to tread carefully to ensure the technology could match the new organizational structure. They had spoken with colleagues who felt they did not understand the differences between systems until it was too late, and were stuck working within the technical limitations of the system they had selected. Suntown's selectors did not want to get taken in by impressive sales pitches and promises of R&D roadmaps. Selectors relied on interviews with colleagues at other agencies, their pilot programs, and the advice of their consultants to help them understand the implications of technical components for their customer service goals. Juliette summarized their orientation around technical goals for the new department in an interview:

> We've been working to study and streamline our customer service, and we have now that conservation and meter reading doing customer service alongside billing we want to understand the evolution of the meter reading position and understand what we need to have in place to maintain this system to pull the data, actively use the data, and get the most out of it.

One way that Juliette and her colleagues learned that they could get the most out of the system was by ensuring the network allowed for near real-time data pings to the meter. Not all systems allowed for two-way communication back and forth to the meter itself. Craig, a sales representative from a firm bidding on the contract, walked the Suntown group through the differences in a shortlist presentation:

> In some versions of AMI, you have the radio that's only transmitting at a data collector because it's only listening. So the radio [on the meter] sends out a read, the data collector hears it, collects it, sends it back to the office. It was a one-way street. One of the benefits of a two-way system that has come along are on-demand reads. That means that if you've got somebody moving out of their house or apartment, and you want to capture that read, rather than having to send a truck out and looking at the meter, you push a button and the software goes out and it actually reads the meter. It comes back and gives you a final read. So you can have an accurate read of when that person left and the starting point for the new resident. Now you can do a lot of metering work remotely. That's what two-way has enabled.

Craig described the system they needed and understood why on-demand reads were important to his potential customers. The Suntown group was pleased with the two-way ability of Craig's system. So much so that they later awarded the AMI contract to the firm Craig represented.

Other firms offered technologies that had a more limited ability for analyst-to-meter communication. For example, some systems collected several hours of interval reads and “bubbled up” the data to the data collectors and MDMS. That meant that analysts would have to rely on data dumps every three hours rather than interacting with the system in a more as-needed or close to real-time manner. Selectors chatted after a shortlist interview about one such system and why they were unimpressed with it:

Camilla: Because of how their system works with those 3-hour interval updates they don’t have as many on demand features because everything is in 3-hour intervals. That made them not responsive to a lot of our critical items. We need to look closely at that.

Dennis: They use the Trident system, so they don’t communicate back to the meter. If you do an on demand read, you’re getting the last read the collector or headend system has, you’re not actually reaching back to the radios. They are very careful. When RFPs want 2-way AMI system like yours, which means signals go all the way back to the radio to the meter, then data gets sent back in. Theirs doesn’t operate that way. They are very careful not to cross that boundary and portray that they do. Whereas [with the other system] it is communicating all the way back to the meter.

Camilla: Is there an advantage to that kind of system that I’m missing?

Dennis: In my opinion it’s simpler. There’s less to go wrong. But their analytics are just gonna be fewer than with the more limited system.

Peggy: Seems like they have a strong product, but if it doesn’t work well with our goals, that’s a deal breaker.

Dennis: Yeah you are not going to leverage their additional analytics. It’s gonna get reads, it’ll pull them back, but I think you hit it on the head. You aren’t performing more communication back to that meter.

Camilla regularly interacted with customers in her position and she understood how 3-hour intervals would limit her and others’ ability to improve customer service with the AMI system. She took a moment to verify she was not “missing” something in the firm’s presentation but emphasized to her colleagues that the technical limitation would have real consequences for their customer service goals. The consultant suggested that the one-way system was “simpler”, but the consultant’s response did not address their takeaway that their new department would be limited by the one-way set up. Peggy was decisive in declaring the technical limitation a “deal breaker.” She and the other selectors gave the firm a low score, ensuring it was not high on the list of desired awardees.

New Interdepartmental Customer Service Working Group

Structural Change. Before selection, members of the ad hoc AMI group reported to senior managers in a monthly AMI update meeting. During the reorganization, senior managers pushed for the monthly meeting to expand to include the participation of more diverse representatives from across the Water Division. The purpose of this was to establish a standing meeting that would facilitate greater applications of AMI data over time. The idea was that if people in water production or water quality heard about the AMI system on a regular basis and saw examples of data applications, they would be more likely to use the AMI system to improve their own operations and better integrate work across the division. The technical implication for this was that data from AMI needed to be easily integrated into a wide range of operating systems and software programs that people used in other parts of the City. To accomplish this expansion of the workgroup and attend to its technical implications, senior managers tasked a new superintendent with the job.

When the new superintendent position was announced during the reorganization, many candidates competed for the post from across the Water Division, but ultimately Peggy was the clear favorite. She had worked for a year as superintendent of water distribution where, in her words, she had “grown a lot,” but she felt the new AMI-focused department was too hard to turn down. When I asked her if she planned to apply, she answered, “I feel I have to go for it. You know, I've been so entrenched with helping with AMI, I think there's no way I can't consider it." Few were surprised when she was hired a month later. Once installed in her new position, one of Peggy's first acts was to organize a way for people across different departments to collaborate more closely and reflect on uses and applications for AMI interval data.

Now as a senior manager herself Peggy renamed and expanded the existing AMI working meeting. Peggy's goal for the group was to orient an expanded interdepartmental AMI collaboration towards a broader vision of customer service. She changed the name of the committee to the "customer service working group," and emphasized that this name encompassed both "external" and "internal" customer service. External customer service meant work with the agency's 30,000 water customers. Internal customer service, which was maintenance on their own infrastructure, had become an increasing focus across the Water Division. The agency's maintenance program was too slow to keep up with infrastructure repairs. Thus, managers were increasingly talking about themselves and their staff as unsatisfied customers and often raised concerns about a growing list of unfinished repair projects *within* the Water Division. David talked about the problem with me on a drive to a regional meeting:

> We're so slammed with existing workload. We have a backlog of maintenance that is a country mile. We lose 10% of our water within our own pipes! If you were a bank, it would totally unacceptable to lose 10% of bank's holdings every month. So, it's unfortunate but we're trying to find ways to deal with that. Peggy has been really involved with our work order management system that a lot of departments use.

The interdepartmental workgroup was one of many efforts that made up the shift to integrate work across historically siloed departments. It was becoming clear that they needed to stop procuring separate and distinct technical systems and prioritize closer integration of data and related work through the systems they relied on in their everyday tasks. Peggy worked to make sure AMI was part of the solution to successful interdepartmental data integration.

Technical Specification. Selectors wanted the AMI system they chose to be well integrated across each of its own components, but also with existing systems in place in the City and the department. They looked to the technical requirements for ways to ensure maximum possible integration of the AMI system into existing systems within the Water Division, but also within other divisions of the umbrella municipal organization. AMI was an important technological facet of the OneWater program, and better integration of disparate systems was an important goal for the department's plans for future reorganization. For example, they wanted the AMI system to work well with the billing software, but also with the Work Order Management System (WOMS) that they used to manage and track water infrastructure in the distribution section. Distribution workers used WOMS to track assets in the distribution system by cataloging photos, serial numbers, repairs, and age. Peggy hoped the AMI system could integrate meter data into the WOMs such that they could better track system health overall. Peggy described future integration plans in an interview:

> In Public Works in general we're trying to work together on coordinating. So we're trying to work together with streets, and with waste water. Long term, the idea is that if they're going to tear up a street and we pave it that first week, they would look to see, "Are we going to replace the water main, or are we going to replace that sewer main?" And do that kind of underground work before they come in and they put in their brand new street, and then we come in two years later and we rip it up and put a new trench in it. That sort of thing. There hasn't been as much coordination in the past, but it's starting to happen. And the WOMS has been a good way for us to start doing that.

A few selectors were anxious about system integration after they had heard alarming stories from other agencies. Colleagues shared stories over the phone and at conferences that they had trouble getting each component to work well together, and as a result had suffered from disparate contractors blaming one another for integration problems rather than resolving it. Suntown's selectors took the extra step of making their desired integrations explicit for bidders. Their consultants produced a customized diagram in the figure below of "existing" and "future" AMI systems for their use during selection and later implementation.

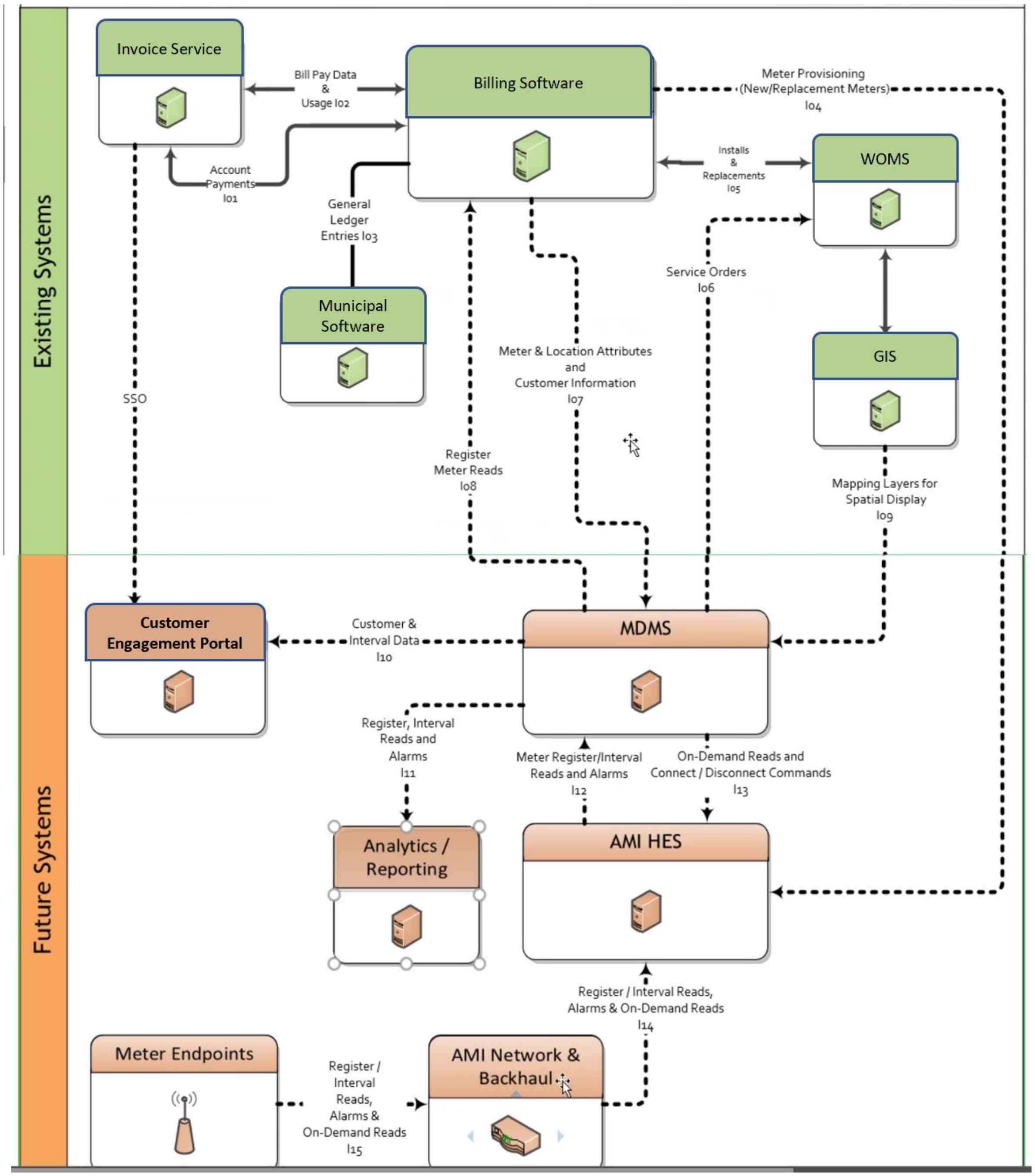


Figure 5.1. Existing and Future Systems.

In the "existing systems" part of Figure 5.1, none of the systems depicted were limited to conservation or the meter-to-cash process. The "Invoice Service" and "Billing Software" were used by every department in the City that billed city residents for services. The "Municipal Software" tracked overall City budgets and expenditures. WOMS was the Work Order Management System used by distribution, engineering, and production, and GIS was used within the Water Division only but other departments planned to expand their GIS tagging operations. One solution they pursued to ensure system integration for the systems in the diagram was to weight a "turnkey" proposal higher in the RFP requirements.

A turnkey proposal meant that one contractor would be responsible for all of the components of the bid. The alternative was to award four separate contracts and hope they worked well together. The following excerpt is from a discussion during the RFP design process, during which selectors were deciding on how to weight different aspects of the proposals:

Camilla: I'd like to just go through and make sure these sound nice to us. I think the fact that [the consultants] has them in there... the only thing I'm concerned about is "turnkey"—[read aloud] is that something that's very important to us?

Manuel: To me the term turnkey is.. I'm not sure the origin, but does this cover everything we've talked about?

Peggy: This turnkey would seem like it'd be a bonus point system where someone submits on all 4 components

Manuel: I think there's value in a one stop shop. The integration is easier. If one company does it there's less intercompany coordination and I feel like it would streamline things. Don't you think?

Juliette: Do we want that enough to give them bonus points?

Peggy: With the turnkey, the big benefit is there's one throat to choke. You only have one person who is being held accountable who is working behind the scenes. Otherwise, the different firms blame each other… "It's the endpoint," "It's the software." If it's turnkey they have to play nice with each other. I'm not sure here it's stipulated in that way that there is one person.

Manuel: What you just mentioned in my mind is that there is benefit during the installation phase—if we don't have to get one vendor to play nice with another and you just made a good argument for that

Sam: I agree Manuel.

Camilla: In this last bullet and we can force a turnkey.

The back and forth in this conversation shows the group in agreement with Peggy's sense that implementation and integration would go better if one contractor were responsible for the overall project. They were concerned that if they hired four separate contractors that each would blame integration problems on the other, with the end result being a poorly integrated AMI system. To avoid this potential headache and its outcomes, the group decided to weight a turnkey submission such that it would force the outcome during scoring. They expected that they would be able to require a single contractor to integrate with their existing systems better than chasing down individual contractors throughout implementation. The implementation of an AMI system was a complicated process that would take at least a year, and the group wanted not only that process to go well, but also to find a contractor who would go a step further and ensure that the AMI system integrated with other existing systems at the City. To the selectors, a turnkey proposal would provide the best chance at getting what they wanted.

A second way the group sought to ensure maximum integration was to require databases to use a standardized interface. Utilities in the United States have their own classification of integration standards for interfacing between applications called

"MultiSpeak." MultiSpeak was developed for and adopted widely by electricity utilities before gas and water utilities began to adopt it as a preferred standard. Selectors designated this as "critical" in the RFP, and contractors who offered it took the time to present it as an asset. The presenter showed a slide similar to the one below in Figure 5.2 and described their firm's approach to integration:

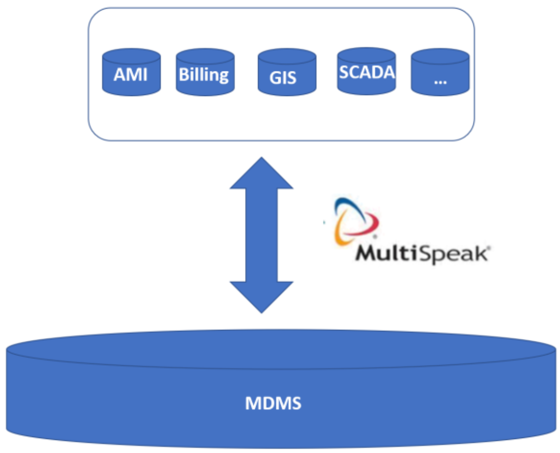


Figure 5.2. Showcasing MultiSpeak as Way to Integrate with Other Systems at the City (Recreated Slide to Protect Anonymity of Firm).

The presenter explained their expertise in building and maintaining MultiSpeak interfacing while showing a slide similar to the one above:

> I have about five slides to talk about integrations. One of the items on the agenda was for us to speak to our integration methodology, and how we integrate with the systems that were proposed in our solution, but also systems at Suntown in general. We extend that to SAS specifically, and of course your billing software. So our approach to integration is typically to focus on getting the meters deployed, getting the reads in the door, and billing every customer, right? What we do for that is ensure the meter verification process and particular integrations or AMI, CIS that you see here are working. In some cases, as part of the initial deployment is we bring in GIS layers to give you that geospatial view within our application. So that's our integration, but it's extensible. We support what the industry calls "multispeak." You

> may have heard of this. It’s more like an industry standard that’s been implemented, similar to CMAP and other formats that are out there. This is a good example of how we are a potentially plug and play system. You want to be able to have proven integrations rather than reinventing the wheel every time.

The firm presenting in this example framed their solution as a “plug and play” integration. They impressed the selectors by demonstrating their experience integrating with Suntown’s billing software at other agencies, and by signaling that they took integration seriously.

Conclusion

Selection at Suntown ushered in the first material implications of technological anticipation. Early anticipatory shaping of predictive frames combined with the departmental reorganization led to a selection process in which the participants were primed to seek out a system that would most benefit their organization in its already changing state. To accomplish this, they wrote bidding documents listing technical requirements that reflected organizational changes that had already occurred or were underway. Three organizational changes influenced the selection process. The first organizational change was a reclassification of conservation specialists and meter readers to data analysts and meter technicians. The new job descriptions required both classes of workers to use advanced data analytics to do work on a computer that was once done in the field. To ensure that they and future data analysts would have unimpeded access to the raw data from the AMI system, selectors required data output to be accessible, rather than limited to pre-established reporting outputs. The second change was a reorganization of metering and conservation into a single department done in order to enable its staff to reduce time in the field and improve customer service over the phone and the customer portal. What this meant technically was that the selectors required that the AMI system needed to have two-way communication and near-real-time pings to the meter for updated data. The third organizational change was an expanded interdepartmental customer service working group, headed up by the new superintendent position. To support broad access to and application of AMI data, selectors required the AMI system to integrate with a diverse set of operating systems and software programs. They did not know yet how a department like Water Production would use AMI data, but they wanted to ensure that it would integrate easily with their existing systems in the future.

These data demonstrate that the material impacts of technologically induced organizational change began not during implementation and use, but actually took shape as early as the selection process. Suntown's ranked technical specifications demonstrated the implications of earlier anticipatory action. In the previous chapter we saw how the predictive technological frames and strategic planning worked to shape a major departmental reorganization. In this chapter we saw how from the process of designing and implementing the reorganization emerged a shared desire and need for specifical technical applications of the future system. This meant people at Suntown did not wait until adopting a system to fine-tune data integrations or reporting. Rather, they ensured *in advance* that the system they bought was capable of performing in the way they came to know that they wanted.

Part II
Unlikely Champions:
When Projects That Should Fail, Don't

An alarmingly high percentage of information technology projects are considered failures by the organizations that attempt them. In one survey, 80% of respondents reported both poor returns on their investment and a disappointing technology outcome from digital transformation projects (Sutcliff et al., 2019). With indications of a high failure rate for such a costly and labor-intensive endeavor, the question of what organizational factors can best support success is a timely one. Studies of strategic uses of information technology (IT) have long emphasized the importance of a project champion (Beath, 1991; Karimi & Walter, 2015; Leidner & Kayworth, 2006). Howell and Higgins (1990) defined technology champions as:

> …the individuals who emerge to take creative ideas (which they may or may not have generated) and bring them to life. They make a decisive contribution to the innovation process by actively and enthusiastically promoting the innovation, building support, overcoming resistance, and ensuring that the innovation is implemented. (p. 40)

Furthermore, they are the people in an organization who stake their reputation on a project's success, and work to "promote their personal vision for using information technology, pushing the project over or around approval and implementation hurdles" (Beath, 1991). Innovation scholars have catalogued the kinds of organizational skills a technology champion needs to be successful. They benefit from being charismatic (Neufeld et al., 2007), transformative (van Laere & Aggestam, 2016) and persistent (Howell & Higgins, 1990). Champions are typically described as energetically pushing past naysayers whose positions are threatened by the change, inspiring others to join the cause, and navigating the murky bureaucratic hurdles of their organization (Rogers, 2010). While it is clear that champions are often pivotal to the success of a diversity of projects, from data warehousing implementation (Wixom & Watson, 2001) to ERP system implementation (Somers & Nelson, 2001), there is still much we do not know about such a critical role in the technological change process.

When students of technological change have looked for champions, they have tended to look to the IT department (Leidner & Kayworth, 2006). It makes sense to seek out champions within the group with the highest concentration of people who have the most technical expertise and know-how. IT professionals can make good champions because they are knowledgeable about and invested in new technologies, but also because they are well positioned to explain the benefits of a new technology and convince others to care about its success (CITES). Champions are not always IT professionals, however. Another role that has received attention in the literature is that of the technology sponsor. Sponsors are typically managers who have the ability to fund or give approval for an IT project (Cohen et al., 2016). They are different from champions in that they have more limited technical expertise, and their role is primarily one of giving a higher status or greater access to the project's champion.

Another, less examined role is that of the users. Technology users are usually positioned in opposition to technology champions. Champions must win over users or if that fails, find ways to outflank them. Conflict between champions and users is a major source of vision conflict on the basis of their contrasting value systems (Leidner & Kayworth, 2006). In the second part of this chapter, I explore the creative strategies and justifications used by a group of future technology users as they champion the adoption of an IT system. Rather than campaigning throughout the organization or publicly staking their reputation on the project's success, they negotiate a high-risk but quieter path to success.

What other kinds of technology champions are there? In this study, I attribute the success of the project to a kind of champion that is not described in the literature. At Fogtown, the champions were not energetic, but rather somewhat demoralized and pessimistic. Instead of promoting the technology enthusiastically to others, they downplayed its potential and talked about it as something much less impressive than when they talked about it in private. Instead of being persistent and pushing through bureaucratic roadblocks, they gave up on the difficult paths and tried something much easier and low profile. The case of technologically induced organizational change at Fogtown reveals a new kind of unlikely champion. Despite many indications of failure along the way, the unlikely champions of AMI championed the project in unorthodox ways and won the prize of an AMI system for their agency.

Selection at Fogtown

Fogtown conducted procurement under much more challenging conditions than their peers at Suntown. Although Fogtown had the signoff from the director to proceed, threats to the project's success were all around them. Primary among them was the potential for protests from citizen activists against any kind of 5G project. Citizen protests were a major threat because many in the water department expected City Council to be sympathetic to a strong showing from the public, however unreasonable their concerns may have been. The small, ad hoc group considered the director's approval conditional on a continuing calm political climate, and that disruption would cause her to fold in the face of opposition. She could pull back her approval at any time. Thus, the group had to navigate a political minefield for the duration of the procurement process.

At the risk of spoiling the ending, Fogtown did eventually acquire an AMI system. When they did, the agency staff expressed a degree of joy and elation that I did not observe at Suntown. Many at Fogtown had placed half-serious and escalating bets along the way for when, if ever, the first AMI meter would go in the ground. When the day came for the first meter to be installed, the superintendent picked the home of one of the more skeptical managers as the place to begin installations. The manager had bet that the installations would not take place until as late as the following year. To his surprise, early one morning a crowd of agency workers gathered out at the meter to yell, cheer, and take photos while one of the women on the distribution team exchanged his old meter for a new AMI one. The manager came outside grinning and admitted that he owed the team the expensive bottle of wine he had promised. I attributed the celebration in part to the relief at accomplishing something that seemed impossible for so long.

How did Fogtown succeed? They pursued an unorthodox approach to procurement that consisted of system disassembly and reassembly. Rather than procuring AMI as a complete and integrated entity like most other agencies, Fogtown's selectors circumvented potential detractors by stripping the system to its component parts. Once broken apart, selectors pursued different procurement strategies for each component, which allowed them to later reassemble the components into a functioning AMI system after selection was complete. The conditions for the procurement strategies they pursued were first that the selected tactic would avail them of a satisfactory version of the component they desired and second, and equally important, the approach would not attract attention from anti-5G activists and their allies.[9]

Selectors employed two sets of practices during procurement. For one set of components, they engaged in lengthy *negotiation* and *augmentation* of an existing contract with a metering firm to secure delivery of a much more expansive set of technologies than was represented in the original contract. Selectors called this approach "backing into" new technology. When they could not back into existing contracts, they used a risky second approach of bidding out the remaining components as "low bid" contracts. The low bid approach introduced risks because it meant that the City would be legally required to accept

[9] See Appendix 2 for a detailed historical background on why Fogtown chose a cellular system over a radio network. Their experiences with breakdowns during an AMI radio pilot led them to believe their topography would be a poor fit for a radio network. The anti-5G activists, for their part, were against both cellular 5G technology and an expansion of radio frequencies.

whichever firm made the cheapest bid, rather than allowing for selection of a better performing firm with a successful track record. In pursuing a low-bid option for the remaining components, selectors engaged in practices of *downgrading* the technology needed and *disqualifying* undesirable bidders. They downgraded the remaining work by using a procurement strategy that was not typically used for complex technological systems, but rather for the purchasing of materials or bidding out construction projects. Selectors avoided the potential downfalls of a downgraded contract by disqualifying bidders who may have won the contract under the given terms but were unable to perform the more data-intensive integration tasks required for the system to be later reassembled. After procuring each component of the system, the group planned to *reassemble* the system with the help of their consultants and integrative algorithms.

Disassembly

Useful Ignorance and Creative Justification. The AMI champions at Fogtown were not IT experts. Members of the IT department were noticeably absent for the entire project. Evan described his interaction with IT during procurement:

> IT has been very perfunctorily advisory. They're not really looped in to and they haven't really been involved in any of this so far. I think the most is I've passed our request for qualifications for the contract installers over to the IT director and pointed out the sections about integration. And say, "Can you please review these and make sure that there is nothing here that causes you concern" and they are like "mm-hmm."

Without IT or anyone else experienced with acquiring a new IT system, the group did not know how to navigate the municipal process to procure a complex and expensive digital technology. Their other attempts had failed to move the project forward, which had caused low morale and skepticism among group members. Their primary goal for procurement was to accomplish it without attracting negative attention. After they were far along in the low bid process, Evan was asked to explain why they had pursued such an unusual approach. He responded by saying:

> In my mind how we got to the whole strategy of low bid instead of RFP was because of what happened before. There was thinking that would be approved more easily… a quieter process… and here we are.

One of the explanations for their unorthodox handling of the municipal procurement process was their total lack of experience with it. Few on the Fogtown team had ever participated in a procurement process, and the consultants were open to working with them to take a creative approach. After he made the comment above, I asked Evan about his experience with the City's procurement process. He laughed and said, "None! Just fake it 'til you make it, I guess!" He explained that he was pretty much on his own to figure out how to approach the project:

> As the project manager for AMI and I got tasked to attend all of these meetings with all the other project managers in the department. In these meetings we would do these workshops which were basically how to manage projects. And so there I was kind of learning about how this is done, but the problem is that AMI didn't really fit very well in their framework, which was mostly about construction projects. And so let's say out of the 16 projects, mine was the only project where they were like, "I don't know. Is this a design bid build type project or—?" No one knew what to do with it. Let's say they didn't really have a lot of chops on AMI projects. They had plenty of chops on building tanks and pipelines and other kind of water infrastructure projects but not really this kind of the AMI project, which is a replacement but it's got this total software aspect to it. And they just didn't know what to do with it. So I've never exactly have a model to follow.

The structures in the city to help people like Evan get up to speed on procurement norms were not helpful for an infrastructure project that had a "total software aspect" to it, and Evan came away empty handed. As a result of what others perceived to be a confusing project, the group was left to their own devices and was often seemingly unaware of the conventions they were breaking.

Fogtown's ad hoc AMI group's first step for disassembly was to assess what components they needed for an AMI system and what their options were for each individual part. As a brief reminder, AMI systems were comprised of four key components. These were the water meter and attached MXU transponder, the backhaul network and connected headend software, the meter data management system (MDMS), and the customer engagement portal (CEP). Of the dozens of water agencies I interviewed, all but Fogtown procured all components as a set in a unified procurement process. Smaller agencies tended to purchase all four from the same provider to stay within budgetary restrictions, while larger utilities with bigger budgets chose their preferred component or the best in breed from different firms through a competitive RFP.

Fogtown's decade-long process of trying out different digital metering technologies meant that they had contracts for pilot programs in place for many of the components. Their assessment produced information about each component, shown in Table 5.1, below.

Table 5.1

Assessment for Each Component

Component	Existing contractor relationship	Procurement practices
Meter and MXU	Contract in place with firm that installed current meters to replace meters as needed	***Negotiate*** existing "Sole source" meter contract ***Augment*** contract to include bulk purchase of new meters with AMI MXUs connected to meter body ***Downgrade and Disqualify****:* Metering contract did not include meter installation or upgraded meter box lids. Agency pursued low bid procurement to contract out to third-party firm for both
Backhaul and headend	n/a	***Augment*** meter contract to 1) function on cellular instead of radio network, which eliminated

		need for agency to acquire third-party network. 2) include headend system to interface with cellular network
Meter Data Management System	n/a	***Augment*** meter contract to include MDMS with meter upgrade
Customer Engagement Portal	Pilot in place with WaterSave system	***Negotiate*** existing pilot program contract to purchase software's enterprise version

This table shows how attractive it was for the group to expand the existing contract with their meter vendor in that one contract could possibly produce the majority of their needed components. Because the City already contracted with the firm to replace broken meters, the group could bypass the open bidding process by opting for a "sole source" clause in the City's procurement process. This would enable the City to contract the firm for new meters, MXU transmitters, a backhaul network, and both the headend and MDMS software all without the public exposure of the traditional RFP. In order to accomplish this, however, the group underwent a year-long process of negotiation and augmentation with the firm.

Negotiation and Augmentation. The negotiation and augmentation approach was not without its own risks. The contracted metering firm only built meters for cellular networks, for example. Had the agency wanted a radio network like Suntown, they would have not been able to pursue the sole source option with the firm contracted for meter replacements. Because the meter shop's experience with the pilot radio network had been error-ridden and disappointing, they were eager to transition to a different type of network. Hunter explained the justification for a cell network over radio to me in an interview:

Hunter: We never fleshed out our system completely but we have been replacing AMR with radios on the fixed network for some years until we started our cellular pilot. I liked the idea of a cellular system. I convinced Evan and Mitch instead of continuing to install the radio system we should go to the cellular option.

Interviewer: Why did you like the cellular option?

Hunter: We don't have to own the backhaul! Another thing is that we really liked was the service that we've gotten with [the company.] We like working with them. They are very responsive and through these pilot projects we have established a really strong relationship. I think the main point is in looking at radio they were telling us to get up to the 98.5% read success rate that is industry standard that we would have to add at least 1 more tower and a number of other repeaters to fill in our system. And we just didn't like the idea of owning the backhaul and dealing with all of that stuff. With cell there is a potential long term disadvantage because we are beholden to the carriers. But the advantage on the flipside to that is the customer base for a cell system is not just the AMI provider, but happens to be every single person that has as cell phone so you have a lot more reliability and leverage because you have such a broad customer base. If the fixed radio system goes down and we need tech support it's just one customer that had a problem instead of 20 thousand or two million. They have lots of incentive to fix down cell towers.

Hunter saw the two benefits with trying to negotiate and augment the existing contract as the opportunity to get out of owning an expensive and complicated radio backhaul network, and continuing to work with a company with which they had had a positive experience during their pilot program. Thus, Hunter was a strong advocate for backing into the meter contract for the majority of the components they needed. Others were anxious about how it would all work out in the end.

The disassembly approach presented some risks for post-procurement system integration. Whereas a traditional RFP approach would have enabled the agency to bundle the project up into a turnkey contract and negotiate a system based on what would integrate best within components, by breaking out components into separate procurement processes the agency ran the risk of one part failing to come through. Mitch was worried about the project and brought up the risks with the group many times. He described some of the risks in this way:

> We're not doing this project in the best way. Ideally we would have done an RFP and as the consultants likes to say, "one back to pat," That's a nice way of saying "one throat to choke." We are doing this piecemeal, so we have a sole source with [the metering firm], a project management contract with the consultants, and we have had go to bid for meter box lids and installation. All of these different pieces! My biggest anxiety overall is not so much data integration but more project success. Will we get everything we need?

Mitch's concern was that if one of the separate parts, like the bidding process for new meter box lids ran into trouble, then the whole project would be stalled, and it would be the agency's responsibility to work out a solution. As meter shop supervisor, Mitch had seen how difficult it had been to get even this far, and he worked hard to make the piecemeal approach work. Even just a few months before starting the procurement process Mitch described himself as depressed about the project and "thinking a lot more about retirement and my boat..." But instead of giving up and letting others negotiate the contract, Mitch threw himself into the project with more energy than I had observed leading up to it, immersing himself in the details and making sure that the contract specified even the number of washers that would be needed. He was anxious, but his anxiety drove him to try to ensure the success of their strategy.

The AMI group relied heavily on their consultants to help negotiate the existing agreement with the metering firm to purchase AMI-enabled meters for their system. They were at first concerned that without an RFP they lacked leverage to get a good price from the firm, but with the right approach they hope to get a contract that everyone could live with. Considering they were looking to buy almost 30,000 meters, they wanted a bulk discount on meter pricing so that they were not stuck with the "street prices" they were paying per meter for replacements. They also wanted the MXU transponder units to be already "married" to the meter to save on install time. Hunter described the process of pushing all parties towards the best deal for the City and the taxpayers:

> When we got the first draft of the sole source agreement [for the meters] it was originally written by the director of the consulting firm. I looked at it and said but you didn't even ask for everything we need!! I rewrote it and asked for everything. They sent back a half-assed answer, and then finally took it seriously. They see contracts like this from all over the world. They told us we could get a better deal. I think if we're paying you for this kind of work, I don't want to be walked down the aisle of a grocery store. I want a tasting. So they got back in touch, and they let 'em have it—! I was like woah! They shaved $1 million off of the deal that we would have taken! So they already saved us $1 million on this project. We're totally pleased.

Hunter's reflection shows not only that he was a hawk for details, but also that with a little pressure on their consultants they were able to get more of their critical attention to their sole source agreement. The pressure paid off tremendously, and Hunter's enthusiasm was shared by the whole team. They often talked up the consultants' ability to save the City $1 million as proof of their value to the AMI project and the viability of their unorthodox approach.

Expanding an existing meter replacement agreement with a metering firm was unusual. So unusual, in fact, that the firm itself was poorly equipped to negotiate the details of the transaction. Their staff were used to going out for RFPs, and did not have the experience or expertise to negotiate an existing contract without clear deadlines or other competitors. When the process became bogged down in process confusion, Fogtown escalated the paperwork to both their own and the metering firm's legal teams to move it forward. Evan explained the conundrum:

> Evan: So the big sole source agreement is the way this deal is constructed right now. It's got this cover letter, and the cover letter says that the agreement shall include all these exhibits. Exhibit one is the master agreement. Exhibit two is the terms and conditions. Exhibit three is the product warranties. Exhibit four is the pricing schedule. Exhibit five is whatever. And one of the crazy things about this whole process, it's like, you would think that this was the first time they'd ever done

something like this, because we actually, they passed us all these different documents, and not all at the same time. And we finally said, this is madness.

Interviewer: Madness?

Evan: Madness! This agreement needs to be clearer because we are including so many different things here. We need to create a cover letter. And so our city's legal had to get with their legal and say, can we do this? Can we do a cover letter that references the exhibits? We put all this organization around the entire agreement, because it was like they couldn't do it. It was like, what the hell guys? It's strange. It's really strange.

Evan's example of the cover letter inclusion was one of many negotiations in the process. In total, the group spent an entire year ironing out the sole-source agreement with the firm to each party's satisfaction. The final contract covered the meters, the MXU transmitters, and both the headend and MDMS software to manage AMI data. Upon the signing of the agreement, the meter shop included a celebratory notice in the department's weekly newsletter announcing the deal and expressing "BIG-BIG-BIG THANKS" to the agency staff for their "tireless attention to detail in getting this massive and complicated agreement for the meters, radios, and AMI data services across the finish line."

The second component for which the group renegotiated a contract was that of the customer service portal. The conservation group had previously contracted with WaterSave for a small trial run of the portal with irrigation customers. Outdoor irrigation was generally the largest culprit for customer leaks, and the agency hoped that by demonstrating new sources of water savings they could build a case for AMI over the long term. As we saw in the previous chapter, the conservation argument had not made much headway with senior management, but the existing contract with the firm still stood and could potentially be expanded. As Evan described it, the CEP contract started out as a temporary proof of concept, but with the AMI approval evolved into a permanent fixture almost by accident:

> In a way we are also backing into the portal just like we were starting to kind of back into the meter contract. WaterSave started out as a pilot, and it was just a tight pilot on the irrigation folks. Then we made a decision to renew the contract just for a year. And I think we've done that maybe two or three times now. Well, it's been fine. I mean, it's a good product. I'm not complaining. It's just that we—here we are once again, kind of—as you know, we're backing into it. We didn't go into it originally for this to be a permanent relationship. Conservation did an RFP for a customer portal for their pilot, right? So they did the RFP kind of exercise to choose WaterSave for the purposes of that defined pilot study. We haven't really done the RFP for the ultimate customer portal, capital C, capital P. But here we are.

By renewing the contract repeatedly over several years, the WaterSave software had become a fixture in the conservation group. Each of the three staff in the group used it on a daily basis, and they had grown to appreciate the data analytics, customer notifications, and water savings tips. Luckily for Fogtown, the WaterSave software was considered a "best in breed" customer portal, and many agencies sought it out as their chosen customer portal. The conservation group was happy to settle on and expand WaterSave, and the rest of the AMI group could avoid the alternatives of a public RFP that would draw attention to the project, or a low-bid process that would require them to choose the least expensive option rather than allowing them to select a higher value portal.

Downgrading

Fogtown's selectors needed to find a way to bid out a contract for both new meter box lids and the AMI system installation work because there were not preexisting contracts for these components. The agency needed new lids because many of the lids in place were made of concrete, which would block cell tower signals and cause batteries to drain. Newer lids were made of a plastic polymer through which the signal could travel unimpeded. The meter and AMI installation contract was also needed. AMI system installation was a much more complicated and technical process than other installation work with which they were experienced because it involved a great deal of data integration with the agency's asset tracking and billing software. In an RFP process installation is typically included as part of the total bid package. The metering firm did not provide installation themselves. Another source of sensitivity for the work was that meter replacement work required a 30–60 minute shut off of customers' water, and any work that touched the customer population needed to be done with great care so as not to incite public relations problems.

Municipalities like Fogtown typically conducted two kinds of contract bidding. One category was a "low bid." A low bid was typically used for construction projects and required the city to select the contractor that submitted the least expensive proposal so long as they fulfilled basic business licensing and contracting requirements. The purpose of low bid options was to ensure taxpayer funds were spent wisely on city purchases like products, tools, and services. The meter lid contract was an example of a typical low-bid contract. The other option was an RFP. An RFP gave cities more flexibility in designing weights with which to assess and award contracts. Selectors could emphasize things like cultural fit,[10] past performance, or technical integration on par with or above the importance of cost. Because a project like AMI had such a wide range of technical options, and because agencies worked so closely with contracts for several years, the RFP was considered better suited to facilitate a positive contract outcome. The norm in the United States for bidding out AMI systems projects was as an RFP. This was so much the case that firms bidding on AMI contracts

[10] At Suntown, one selector took issue with the fact that a contractor was smoking a cigar during an online interview. Even though the interview was remote and secondhand smoke was impossible, a few of the selectors considered the cigar a sign of a poor cultural fit during their RFP scoring.

looked at low-bid procurement with some degree of suspicion. Craig, a sales representative from an AMI firm that bid on and won Suntown's contract, explained the difference in this way:

> Craig: It's funny, we just ran into a low bid situation in Ohio where we actually passed on a project. Typically, this not the way these systems are done. It's usually by an RFP rather than a low bidder. In Ohio they had a bid, and the bid was very restrictive. And it actually said that if you put in a bid and you're selected and you don't choose to move forward and accept our terms, meaning all of our terms are set in stone and you can't change anything, then as a firm we would have a financial risk with our bid bond. We passed on it because typically these negotiations go on for weeks and weeks. You have to negotiate terms! In all the time I've been doing this, I've never seen anybody sign a contract without any negotiation.
>
> Interviewer: What are low bids usually for?
>
> Craig: Construction, mostly. I mean we are a big firm with lots of divisions and they do low bid construction projects all the time. And to me that's because there's only so much variation we can do when you lay down a road. Everybody pretty much does it the same way. There's gravel and asphalt and equipment. But AMI's a lot different. It means a lot more nuances in doing an AMI system than building a road or a building or a bridge. This market is mature, and a lot of these utilities have been through something similar already with a previous [AMR] system. And so they're aware that you can't treat it like a typical construction job.

Craig's understanding of which procurement strategy was appropriate for AMI was shared by parties on the municipal side, as well. IT departments and project managers preferred the RFP process for digital systems acquisition to allow them to select out affordable yet high-performing technologies that would work with the technologies already in place. The idea of procuring a digital system through a low-bid process was unusual because it forced cities to select potentially underperforming systems that could wreak havoc on billing, IT, or data integration tasks. With the norm so firmly established for AMI procurement processes, why then did Fogtown pursue a low-bid approach for the AMI installation portion of the project? The primary reason was to facilitate a smooth approval process through City Council.

Selectors at Fogtown expected that the City Council was unlikely to pay much attention to a low-bid contract. Low-bid contracts were usually passed on “consent,” meaning they were read aloud and then voted on in a single motion. An RFP, by contrast, often involved discussion and questions by council members, and the opportunity for public comment. After the desalination plan fiasco, jitters about the public comment period during city infrastructure projects were widespread. Consent was a safer path to Council approval. In fact, when I attended the Fogtown City Council meeting when the installer contract came up on the agenda for a vote, I could have missed the consent process entirely if I were not paying close attention. The proposal and vote lasted less than 90 seconds. Before taking the final contract to Council, however, the group first set about disqualifying undesirable firms.

Disqualifying

The AMI workgroup worked to organize the process in such a way that would not leave them forced to award a contract to a firm they perceived as having a high risk of failure. Thus, the proposal they developed involved a two-step process through which they could disqualify contractors early on in the process. Contractors were first required to submit “statements of qualifications” (SOQs), after which those who satisfied the technical qualifications would be invited to submit formal bids. Of the formal bids, the City would then be *required* to select the lowest dollar offer. This made them nervous. Thus, Fogtown’s use of technical qualifications was different from Suntown’s in one important way. Fogtown’s selectors used technical qualifications as a *process* to exclude a contractor they thought would do a lower quality job. They did not use technical qualifications to achieve specific technical components from the system, as they were relatively satisfied with the system proposed by each bidder. In an SOQ review meeting, Hunter expressed his hope that they could use the SOQs to eliminate undesirable firms and avoid the requirement to award them the contract:

> My question is what kind of safety net do we want to put in here for our technical specs so that we aren't stuck with the lowest bidder. There needs to be some specificity in the technical specifications so we have something to hold them to if we end up in contract.

Hunter looked to the technical specification for a way in which to either exclude a bidder, or at least require them to go beyond their offering in their initial proposal. If the firm could not propose photo documentation of each installation, or if they did not have a way to track serial numbers on the agency's work management system, for example, those shortcomings could be reason to argue that a firm was not technically qualified to submit a low bid. Thus, the group could trigger a technical review process after the SOQs were submitted if they wanted to limit the pool of bidders.

On the due date for the SOQs, three contractors responded. The group was pleased at first because they had hoped for at least three respondents. Upon reviewing the submissions, however, it quickly became apparent that one of the bids was not up to par. Evan summarized the situation to Hunter at the beginning of a workgroup meeting:

> To catch you up, Hunter, we got three SOQs back. Two firms that Sobel anticipated we would see. The third bid was from Davidson who I think was a bit of a surprise to them. And the Davidson one was pretty skinny on actual details with regard to the project. Two thirds of what they gave us appeared to be their warehouse safety manual. They did not acknowledge any of the addenda or appear to have even *seen* the addenda because they did not provide their statement of qualifications in the format that was requested. So we'll scrutinize that SOQ pretty hard and decide if we want to include them in our shortlist. Based on what I've seen so far I have reservations. We'll be beholden to the lowest bid—and this looks like there would be lots of change orders and headaches along the way.

Evan was clearly unimpressed with Davidson's effort. It seemed to him like the firm had not even bothered to read the requirements. This did not bode well for a future collaboration that depended so much on close attention to detail and aversion to error. The only way to avert their attempts to bid was to disqualify them on the basis of their first submission. If there were technical shortcomings in the SOQ, they needed to identify them and assess whether they justified exclusion. Fogtown's consultants were wary of excluding the undesirable firm, and shared their reasons as they discussed the agency's options:

> Hunter: Two questions. Do we invite Davidson to bid and what specifics do we want to put into the low bid so we get what we want when we get a dollar number.
>
> Consultant: Becky, are there any technical scores that can carry into the low bid?
>
> Becky: Correct. That's the way we structured it. We could have done something different but we didn't.
>
> Consultant: Once we go to low bid it's purely cost. Is it pennies? Or some discretion?
>
> Becky: Literally the low bid. To the penny.
>
> Consultant: Just making sure that was accurate. Do we include all three? What details do we need to put in the bid to finalize it. My recommendation is to include all three. I'm open to debate on that, but from a cost standpoint, it's better to have three than two. And the industry is very small word will get out if someone gets excluded. The other two will find out and put the price up. The counter part is, if we aren't comfortable with one of them—we shouldn't leave that open. I personally didn't see anything that would lead me to believe that any of the three can't deliver.

In this exchange it was apparent that the AMI consultant was unfamiliar with the low bid process and relied on Becky's experience with municipal purchasing to clarify the terms. Their advice throughout this stage of contracting was to retain all three prospective bids. Others at the agency felt differently, however, and elected to score the SOQs for technical qualifications. To exclude a contractor from the process, the selectors were required to follow municipal code and undergo a scoring exercise of each SOQ.

The technical scoring process was sometimes a little awkward. The consultants were relatively unfamiliar with the SOQ process; Evan, Hunter and Mitch wanted to use the scoring to disqualify Davidson; and Becky felt that there were no real reasons to disqualify anyone. Becky expressed her concern during the technical scoring meeting and tried to exclude herself from the process:

> I have to be honest, I'm not a technical person on this and I would feel uncomfortable scoring. When I read through the SOQs I'm not looking at it from a technical perspective, I'm looking at it more of a compliance perspective, asking if they can they comply. I thought all of them were compliant. I'd say everything is a 4 [out of 5] and that's not fair for what we're trying to do here. I think it should be Hunter and Evan scoring these, not me.

The consultants encouraged Becky to participate and tried to facilitate the process in a way that the group could come to a consensus through scoring. They assured Becky that most agency staff were coming from a "technical perspective," and that their job as consultants was to help them through a technical review to ensure they got the system they wanted.

> Peter: We don't always have technical folks on the scoring team for clients- because you looked at it from the compliance perspective if you agree or disagree. And if you add your perspective, great, and if you are OK with their scoring, that's great. And there are other categories where compliance is strong. Hunter you said 4 for RoundLake. Evan?

Evan: Aahhhhh I'll give them a 4.5.

Peter: No decimals.

Hunter: Integers, Evan. Becky, we are doing this by consensus, so if we come to a consensus and you can just say if you disagree and it's good to hear any of your input. We need you!

Becky: OK I'll stick around.

Peter: So for Davidson… 1–5?

Hunter: I give them a 3. And I can provide an argument if it's necessary.

Peter: We'll get to that later.

The scores that the group gave each technical component were less of a fixed judgement than a means to differentiate. The group knew which firms they liked (Lovind and RoundLake), and which one they didn't (Davidson), thus the score for Davidson needed to be lower than the threshold for advancement to the second stage of the bidding process. Becky felt uncomfortable, but she, Hunter, and Evan had built up a degree of trust and camaraderie over the last year and Hunter did not want to lose her valuable input and perspective. Luckily, she agreed to stick around, even if she expressed her discomfort and disagreement with the process several more times in the same meeting.

Peter, one of the consultants, put the matrix from Table 5.2 on the screen and talked the group through scoring in a meeting after interviews with each of the firms.

Table 5.2

Technical Scoring of Bids

CRITERIA	Firm 1	Firm 2	Firm 3
WORK ORDER MANAGEMENT SYSTEM - 30%			
Software Application, Dashboard and Field Device	Pros: real time access, live mapping. Cons: Questions: GPS accuracy of 5-7 meters; req't is 2 meters (request pricing at both levels?) Whats the definition of searchable data? How many meters using this platform? What mapping engine is used?	Pros: real time, smart phone based Cons: Lacked detail - didn't really get a good picture Questions: 24/7 support? Didn't say if they would meet the accuracy requirement.	Pros: real time data sync Cons: no live dashboarding Questions: 24/7 support? How many meters using this platform? What mapping engine is used? Is there an available dashboard? What is premise level accuracy?
Flexibility of Software to Accommodate Workflow	Pros: Cons: Questions: unclear if workflow is customizable	Pros: Survey questions can be added Cons: written response was for inside and neptune meters Questions:	Pros: flexible to meet requirements Cons: Questions:
Flexibility of Software to Collect Required Data	Pros: Cons: Questions: Can you acknowledge the MIU during install?	Pros: will validate the MIU before finalizing install Cons: Questions: Will need to have beacon hockey puck (endpoint installation tool) to acknoweldge the MIU - is this what they are using?	Pros: flexible to collect data Cons: Questions: Can you acknowledge the MIU during install?
Interface/Integration Capabilities	Pros: Cons: Less information than others Questions:	Pros: stessed city staff involvement, workshops Cons: inconsistency with schedules Questions: 5 months for mobilization, but show 30 days. Deployment is 18 months, but stated they could do 12 months?	Pros: requirements workshop, develop workflow based on city requirements. Comprehensive (included billing system name) Cons: Questions:
INSTALLATION MANAGEMENT - 20%			
Project Management and Reporting	Pros: inventory is assigned to installer Cons: Questions: where do you expect to warehouse	Pros: inventory checked in/out daily Cons: no additional details from WOMS; informatino not available online Questions: where do you expect to warehouse	Pros: inventory is assignted to installer. flexible with reporting requirements Cons: Questions: where do you expect to warehouse
Installation Polices and Procedures	Pros: example SOPs Cons: didn't address box issues Questions: describe customer claims process	Pros: Cons: Lacked specifics of field condition, concerns about their awarness of issues Questions: describe customer claims process	Pros: SOPs (included customer claims) Cons: Questions:
Training	Pros: detailed 3 days/7 days Cons: Questions:	Pros: background checks, details Cons: Questions:	Pros: Cons: less details around timing Questions:

They repeatedly checked to see if the group wanted to take Davidson out of the process.

Peter summarized the state of the bid for the group:

> For Davidson, I was expecting less from them but I think they actually presented really well. They fell flat with the barcode scanning and the photo reviews [third-party reviews photos of each meter installation to ensure quality]. Evan, you asked how much they review and they said 10%, not 100%. Their answer was "we used to do that." OK… well… why not anymore? It was funny. I think the summary is for this part of the technical review we are trying to make a decision. Do we allow all three to bid? The next phase is low bid. Are we comfortable with all three participating? We think we can push Davidson, and maybe RoundLake up to the same playing field, same level, by requiring things like barcode reading and 100% photo audits that we liked from Lovind or RoundLake. We don't have the risk of the low bid that also doesn't meet our requirements. If we are careful of the scope of work—we might be able to push Davidson into a technical threshold where we are comfortable.

The consultants were wary of disqualifying anyone because unlike the agency, they would continue to interact with and work with any contractor who was cut out of a bid process.

They requested several times for me to not take notes on side conversations in which they expressed privately that it could hurt their reputation in the field. They were worried that if cities and firms heard that they were behind unorthodox exclusion practices, that they would look biased or even unethical.

The group completed the scoring process and decided to disqualify Davidson. Becky disagreed with the decision, but supported the group and did not attempt to block the disqualification. She asked that Evan talk to the director to give her warning of the decision just in case the firm decided to protest the decision. Evan agreed and met with the director. He summarized that meeting to me in an interview:

Interviewer: Tell me how the conversation went with the director about the decision to exclude Davidson from the bid.

Evan: So I called Hope up and I tried to summarize the points we agreed and disagreed on in the group. She asked a few questions. One of the questions—she's really kind of astute this way. She said, "Well, hold on a second. Can a vendor make a big protest if they haven't yet made a bid?" And I laughed and said, "Gosh, I don't know." And she said, "Well, you guys are worried about this bid protest. But what you are saying is that you're not going to even allow them to bid because you're not inviting them. So what rights do they have to make any kind of protest right now at all?" So we checked with the city attorney. And even though our request for qualifications describes the possibility of being uninvited, it turns out that there's law. It's basically state law here that allows people who are in a prequalification process to protest if they've been uninvited.

Interviewer: So there is a risk?

Evan: Yes, but we didn't know that just at that moment. So she said, "Let's say for the sake of qualification—for the sake of the conversation, that they can protest." She said, "I think that the reason we did this whole prequalification process in the first place was to be able to disqualify someone from going forward." And so she said, "If you guys are feeling like you've done a good job in your evaluation and that there is a certain level of risk associated with one of the firms that makes you feel like it could turn out poorly or could just result in maybe more work on the behalf of the city to manage the firm, then this is exactly the reason why we're doing a pre-qualification process."

Interviewer: That's interesting.

Evan: So she was essentially in support of us disqualifying someone if we felt like there was good reason to disqualify them.

After this conversation, the consultants sent a letter to Davidson to inform them of their disqualification. The firm did not protest the decision. Before the submission of official bids, however, one of the firms decided to pull out of the process. The group was surprised and dismayed that this meant they were down to a single option for the contract. Peter called the firm that dropped out to find out what had happened, and learned that they had been "spooked" by the low-bid process. He reported back to the team that "they don't usually go for low-bid contracts, and feel that their services are a high quality and unlikely to come in at the lowest price." Thus, Fogtown had only one option for the installation contract.

Reassembly

Some on the procurement team were concerned with the component and data integration required for reassembly. For those who worked more closely with the billing department, it was important that the data integration between components function without error. By separating components out individually, there were no guarantees that the data needed between components would be communicable. Even a small error could have catastrophic effects on the agency's ability to bill customers in an accurate and timely manner. Sending out even one cycle of incorrect bills could have a long-term effect on public perceptions of the agency and customer trust. The installation of the meters would be separate from the meter purchase, for example, but both the meter ID and the installation date needed to go into the City’s existing asset tracking and billing software. This was important so that they could keep track of which meters had been installed at which customer’s addresses and align them with the correct volumetric read schedule. New meters started at zero consumption, and the billing system needed to account for why the total consumption on a meter was lower than the month before through the meter exchange data. One way that the group looked to ensure integration was through task delivery required of the project management consulting group. Included in their contract was the delivery of up to 12 algorithms that would link the new AMI software to the agency’s existing systems and produce useful reporting outputs. The task delivery in their scope of work was outlined in three steps:

> Step 1: Sobel will work with the City to define what use cases are important and align with data sources.
>
> Step 2: Sobel will perform a gap analysis to understand the ability of the City’s existing software to provide the necessary use case information. Gaps in outputs or reporting will be documented for inclusion in the Analytics development.
>
> Step 3: For each use-case identified for development, a tailored algorithm with input/output, triggers/thresholds, and insights will be developed. Sobel will collect and clean the necessary data sets, including the timeseries data and will request a static export csv or an equivalent format. Data will be reviewed, cleaned and arranged in a format, likely a database, stored on a Sobel server.

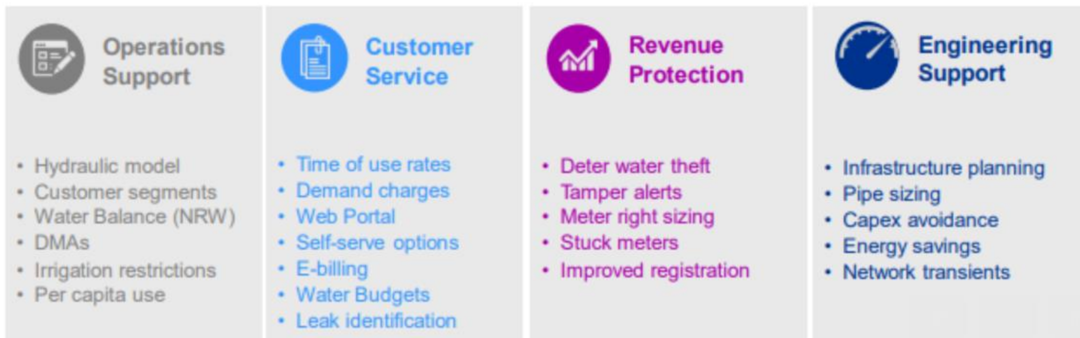
For Evan and others on the team, the promise of future algorithm development in the scope of work functioned was a palliative for their data integration concerns. Whatever happened during procurement and implementation, they could turn to the consultants to stitch disparate systems together to make them work.

After selection and several months into implementation, Evan initiated a conversation with his colleagues about the reassembly process. Whereas at Suntown there were discussions of novel use cases for AMI and interdepartmental integrations in the very beginning stages of learning about AMI, at Fogtown this did not happen until much further along into the process. The consultants were responsible for a sequence of numbered tasks in their contract. Evan sent out an email when the phase arrived during which the consultants were to begin business operations assessments and algorithm developments. The email, with the subject line “Meter interval data, algorithms wanted,” went out to about a dozen people within the division. In it, shown in Figure 5.3 below, Evan asked his colleagues to think creatively about how they might use AMI data.

Figure 5.3. Email to the Division.

Hi folks,

As part of the Meter Replacement Project, Sobel (project management) will lead us through a task where we investigate the potential for meter interval data to enhance various operations. This handy graphic lists a few examples:



The City needs to come up with 12 use cases we want to explore, and I'm reaching out to **YOU** to see if you've got an idea you want to enter into the running. Here are some ideas I've heard so far:

- Leak Identification – to better inform our future Leak Response Program, we'd like to take a look at the distribution of leaks by type (volume/duration) in order to understand where best to focus our notification and enforcement efforts with customers
- Dead-end Flushing – to better understand how often we ought to flush dead-ends, we want to take a look at customer consumption to see how much water is moving through these aggregated services throughout the year
- Meter Right Sizing – we want to look at instantaneous demands and overall throughput to determine if we have the right sized meter for the job in any given service location
- Real-time Sales Reports – sales reports are always delayed because billings happen in arrears, so we want to look at sales without this lag—or compare forecasted billings to actual billings
- Use Patterns by Customer Class – Doug would like to feed this data into the hydraulic model to get a sharper picture of what's going on
- Blue Coast District Metering Area – water in VS. water out VS. water consumed through customer meters… How wild is the wild wild Blue Coast?
- Right-sizing PRVs – Rory would like to see aggregate consumption in these areas to see if our PRVs are properly sized
- Water use & Affordability – we'd like to see how water is used in disadvantaged communities, or other low-income designated areas, especially, perhaps, in regard to tenant-account holder vs. landlord account holder properties

If you're interested in developing a use case involving interval data—or you know someone else who is—please let me know.

The detailed examples Evan gave in the email were ambitious, creative, and dependent on interdepartmental collaboration. They contrasted with the more restrained and limited applications that Evan and his colleagues emphasized prior to selection. We do not yet know if Fogtown succeeded in any of the proposed use cases, but the combination of the consultants' expertise and Evan's efforts to coordinate among his colleagues point to at least one possible future in which Fogtown might successfully build a more expansive AMI system than their early efforts indicated.

Conclusion

In this chapter, two agencies organized to select an AMI system in categorically different ways. Suntown's experience showed the ways in which anticipatory activities at the adopting organization shaped a process that allowed for extensive customization of the material properties of the technologies they acquired. Fogtown's selection process revealed how anticipation helped produce a process of disassembly, and the related practices of negotiating, augmenting, downgrading, and disqualifying enabled champions to succeed in adopting a digital system when politics threatened to block their progress. Fogtown's process limited its ability to choose among technological specifications for their system.

At Suntown a diverse group of selectors was influenced by anticipatory organizational changes in their procurement process. The experience of deciding on and going through a reorganization in advance of adoption and implementation of AMI shaped the desired technical specifications for the system. The organization change they were already undergoing influenced what they wanted out of their AMI system. To acquire a system that met their updated technical requirements, the group labored over a detailed set of appendices to the public RFP and required potential contractors to supplement their proposal with clear responses to hundreds of specifications. When a contractor could not fulfil an important function (e.g., could not provide total access to the raw data from the AMI system), their bid lost points in their overall score. Analysis of Suntown's procurement process revealed at least three ways that anticipation shaped the materiality of the digital technologies eventually acquired by the organization. Selectors at Suntown developed detailed knowledge of AMI in ways that shaped their desires for their own future system. By organizing in advance of even knowing what technologies they would adopt, they grew to appreciate the differences in capacities among component types. Rather than adopting and adjusting through use, people at Suntown acted on the information they gained in advance of technological change to restructure and orient towards the future in ways that were consequential to the system they adopted. Their experience reveals a novel way in which anticipation shaped process and materiality during selection.

Fogtown's process was led by selectors who became unlikely champions. They had little to no experience adopting or implementing a technological system, but still they worked for years to bring AMI to their agency. The way in which they had anticipated AMI before selection had routinely downplayed the technology in ways that left them with few options during selection. Thwarted by a hostile, anti-5G political climate and risk-adverse management, a small group creatively navigated their organization to find new ways to facilitate technological change through a strategy of disassembly and reassembly. Guided by their mission to avoid excess public scrutiny, they repurposed both existing relationship structures in the form of existing contracts and alternate structures in the form of the low-bid procurement process. This process limited their options for the technologies. Instead of the expansive set of options enjoyed by Suntown, Fogtown had only a single option for each component. Although it was high risk, the Fogtown champions did what defines champions in all sectors by overcoming the odds and taking on risk to succeed and celebrate an unlikely accomplishment. During installation, they began the initial work to reassemble the components into a system, indicating that they might build a digital system that was greater than the sum of its parts after all.

VI. Conclusion

Future Perfect Organizing:
Why Anticipation Matters to Scholars of Work, Technology and Organizations

That sanguine expectation of happiness which is happiness itself.

JANE AUSTEN

I began this dissertation with the argument that technologically induced organizational change may begin much earlier than we have previously thought. I suggested that organizations anticipate new technologies in ways that alter their social and material structures in advance of even the selection of a particular artifact. To answer the questions of *whether* this were true and, and if so, *how* it manifested in organizations, I designed a study to focus on a window of time several years before an expected[11] technological change at two organizations. As it turns out, the period before technological adoption is rich with anticipatory activity. I presented data that showed how at both organizations I studied there were processes of prediction, decision making, and organizational action that were motivated by what actors perceived to be the digital future not yet arrived. What I found calls into question several fundamental assumptions about the process of technologically induced organizational change.

The data showed how anticipation conditioned the process of selection and the related materiality of systems that organizations will later implement. In both organizations people undertook everything from subtle adjustments in the organization of ad hoc work to major reorganization projects that affected people across multiple departments. There are two reasons

[11] I have used the verb "to expect" to refer to the cognitive process of regarding something as likely to happen. Anticipation is different from expectation in that it is based in action.

that anticipation is important to scholars working to understand how technological change shapes work and organizing. First, anticipation is important because it is the ground from which subsequent changes emerge during implementation and use. Second, because anticipation begins with perceptions of the future, it explains how technologies can shape organizations before users can physically interact with them. As a means of perception and action, anticipation is a fundamental quality of human agency. Understanding these two implications—that technologically induced organizational change happens sooner than we thought and that it does not rely on access to the material artifact—together is the beginning of an explanation for the how, through anticipation, the probable future impacts the present.

Change Before Implementation

The first and most apparent assumption my findings call into question is about *when* technologically induced organizational change begins in the adopting organizations. I designed my research to focus on a previously overlooked period several years before two organizations adopted and implemented a new digital technology. Studies of technologically induced organizational change are almost always designed to capture data during or after implementation, thus an organization's "implementation line" has long served as the point at which we have designated as the "beginning" of technologically induced organizational change (Leonardi, 2009). Reliance on implementation as the starting line has shaped research that positions the adopting organization as if preserved and protected against influence from the outside until first contact. I have shown that the barrier between organization and new technologies is permeable, if it exists at all. Through the process of anticipation, new information, ideas, and predictions about the future filter into the organization. By beginning my data collection years in advance of an expected technological change, I was able to observe a complex set of anticipatory changes that shaped both the structure of work and the materiality of the technologies the organization eventually selected.

While we have a rich literature that investigates the implications of implementation and use, we know little of what may take place prior to the arrival of the material artifact. Theories we rely on to guide understanding of change, like the social construction of technologies (Bijker, 2012; Pinch & Bijker, 1984), Marxian theories of deskilling (Attewell, 1987; Barley, 1988; Braverman, 1998), or sociomaterial theories of structuration (Barley, 1986; Desanctis & Poole, 1994; Giddens, 1984; Jones & Karsten, 2008), do not take activities at the adopting organization in advance of implementation into account. Thus, until now, we have had very little to explain the implications of potentially earlier processes of change. The differences between how we have thought about technologically induced organizational change and how I have described the phenomenon in my dissertation are depicted below in Figure 6.1.

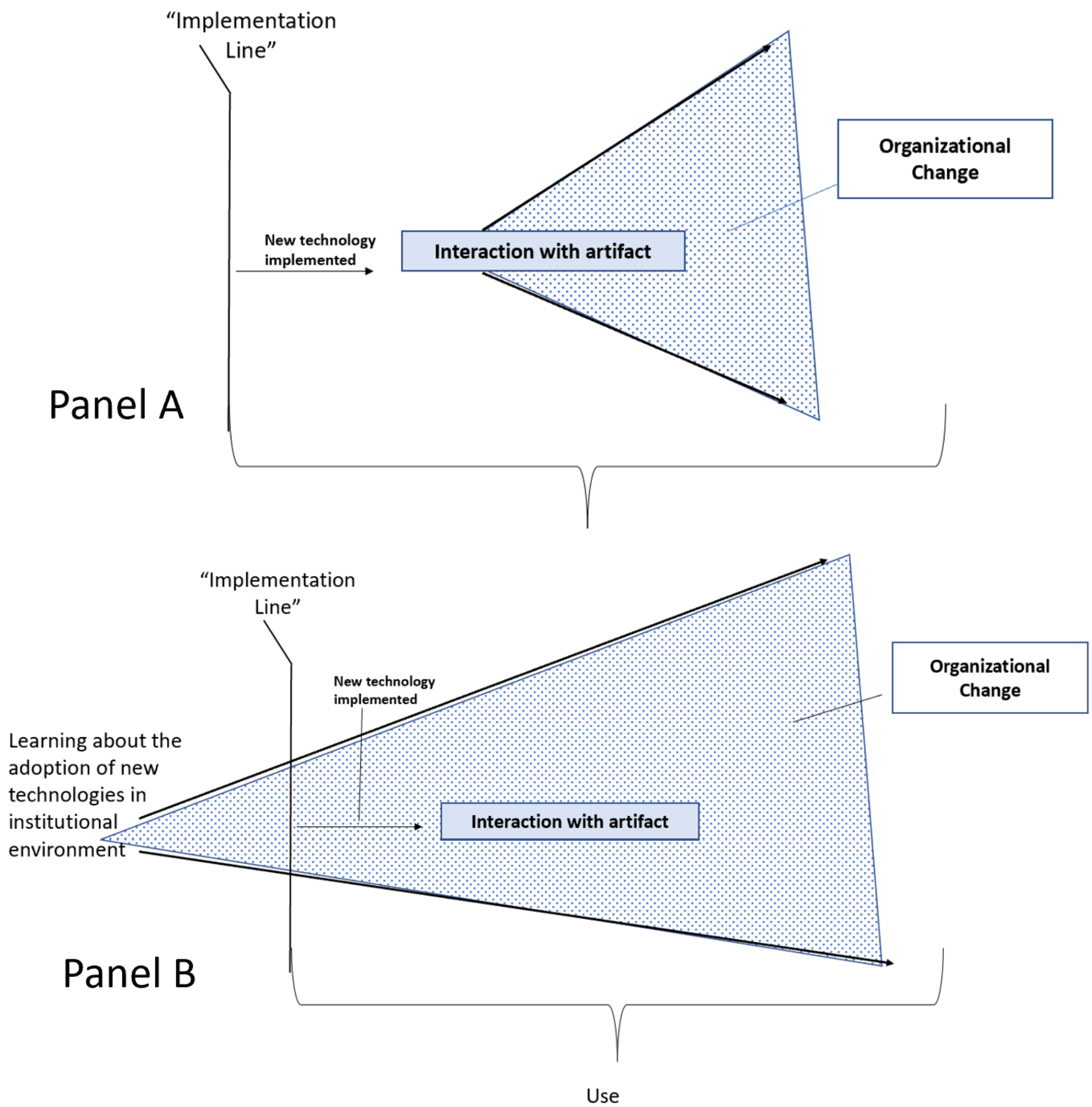


Figure 6.1. Change and Interaction Before and After Implementation.

In Panel A in the figure above, organizational change begins with users' interaction with the artifact. Organizational change does begin and end with user interactions, especially given that, as Bechky (2020) emphasized, "in the digital age, it is important to understand how technologies may change even those occupations that do not directly adopt and use them" (p.

607). As a process, however, scholars still look for the beginning of the process at the point where users within an organization begin to interact with those technologies. In contrast, my findings suggest a different model of the sequential process of change that begins much earlier, shown in Panel B.

A study of anticipation asks us to consider what happened *before* the phenomena that we have so far uncovered from research in organizations. We often explain technologically induced organizational change as a process-based phenomenon, and thus anything that happened earlier than what we already know is important to building a full account of a phenomenon. What happens, for example, before financial traders get their hands on the new technologies that have been studied in investment banks? How might anticipation have shaped the processes of performativity (Beunza, 2019; MacKenzie, 2006), "blackboxing" (Anthony, 2018), and transformative shifts in identity (Barrett & Walsham, 1999)? Extending our process models backwards to the first instances of perception and anticipation has as much potential to complicate what we already know as it does to elucidate it.

My dissertation is only one example of how technologically induced organizational change begins before implementation. My study shows how anticipation shaped pre-implementation decisions about the maintenance of key infrastructure, the formal organization of work, and the material qualities of the digital systems that the organizations selected. Each of these are important to both the organizations that experienced them and the scholars who study related phenomena, but there are likely many more implications of technological anticipation than I was able to capture in my own data. As I discussed in some detail in Chapter 1, one reason for this limitation in existing theory is methodological. Scholars of technological change almost always design studies of organizations to begin data collection during or after implementation. Despite the standard of limiting data collection, in Chapter 1 I explained the many indications of much earlier change within the findings of the studies themselves.

When can new technologies first "touch" the receiving organization? In Chapter 3, I showed how people began to build predictive technological frames upon first learning about the existence of new technologies. At both agencies the development of frames was more than a cognitive exercise. Instead, frames shaped action and structure in consequential ways. For example, at Suntown Peggy and David had just begun learning about AMI when they needed to make a major decision about replacing the City's entire metering system. Influenced by their predictive frame that the eventual transition to AMI would take time and careful consideration, they decided to avoid meters that would limit their options. They sought out firms that built meter bodies that could support their transition to one of many AMI systems in the future. This was not an easy task, as most firms in the industry at the time built proprietary metering software that would have made the system path dependent in the future. Instead, David opted for a meter produced by a firm that sold cellular-network-based AMI systems but whose commercial meter body had built-in connections that allowed for connections to a third-party AMI technology. This meant that the material technology David put in the ground in front of 30,000 water customers' homes had been already shaped through anticipation of a future AMI system. At both agencies small, ad hoc workgroups progressed through one or more sequences of organizational action and information seeking that shaped evolving predictive technological frames.

Not only did anticipation shape ideas in the form of predictive technological frames that people had about their organizations' technological futures, it contributed to novel instances of decision making and change management that were wholly initiated and justified by the coming technological change. The data I presented in Chapter 4 demonstrated instances of organizational change that emerged from the practice of anticipatory control. I showed in Chapter 4 how the enactment of anticipatory control conditioned changes both in daily work practices and chain of command at Suntown, and in the rate of decay of the material infrastructure at Fogtown. At Suntown, the top-down anticipatory actions of upper-level management helped to bring about a departmental reorganization that altered the job titles, job descriptions, and formal organization of dozens of people within the Water Division at Suntown. Suntown managers were matter-of-fact about the reorganization, despite it being the first recorded instance of a departmental reorganization justified by a technology not yet arrived. This suggests that the process of adapting to new technologies through anticipatory control was an extension of their management practices at the upper levels of the agency. At Fogtown, a seemingly benign decision by senior managers to withhold repair budgets from metering and distribution work was meant to prevent the unnecessary spending of funds to repair infrastructure that was "about to be replaced anyway." The decision helped to trigger a precipitous decline in the functioning of Fogtown's metering system and the relationships between the staff who relied on and maintained it. The subsequent uptick in concern expressed by members of the public and the intensifying friction between billing, metering, and distribution workers who struggled to do the basic work involved in the meter-to-cash process were examples of unintended side effects of an instance of anticipatory control.

Anticipatory action was consequential for both the formal structure of the organizing and the material infrastructure for which the water agencies were responsible. I showed in

Chapter 5 how anticipation shaped the component-level configuration of the anticipated technologies themselves. In embarking on their selection process, Suntown's selectors had an approved budget that would enable them to procure any of the AMI systems available on the market. Their research, pilot programs, and experience in proposing the departmental reorganization had all worked to shape their desires for specific technological affordances of the system. The anticipatory organizational changes that were initiated at Suntown's agency influenced selectors' work in drafting an RFP, scoring responses, and selecting a final set of firms. They accounted for three organizational changes in designing technical requirements for the contract: job reclassification, the merging of two departments into one, and the expansion of an interdepartmental workgroup. Supported by consultants and subject matter experts, Suntown's selectors were able to identify and require specific coding standards, database integration requirements, and database access thresholds. Thus, we saw in Chapter 5 how years of anticipation led to a more informed and technically rigorous selection process at Suntown. Contractors bidding on Suntown's AMI system often expressed that they were both surprised and impressed with the level of technical knowledge of the selectors in comparison to other municipal workers with whom they had interacted.

My findings call into question how we have positioned the implementation line in studies of technologically induced organizational change. I have shown that before implementation there is anticipation. Without incorporating the phenomenon of anticipation, the implementation line functions as a metaphorical Lagrange point[12] in organizational space

[12] Lagrange points, named after Italian-French mathematician Joseph-Louis Lagrange, are positions in space where the gravitational pull of two large masses cancel each other out such that a third object does not require propulsion to remain at a fixed point. Moving closer to either of the two large masses will cause the third object to be subjected to its gravitational pull and fall into its orbit. On one side of a Lagrange point, an object is subject to the gravitational pull of the first mass, and on the other side of the point, it is subject to the pull of the other. Like the moon's gravitational effects on the Earth while in orbit, the gravitational pull goes both ways.

and time. This has meant that researchers analyze technologies as they transit between two types of organizations: those designing and those adopting new technologies. For answers about the impacts of a new technology scholars have looked to the organization with greater "gravitational pull" on either side of the moment of implementation. For technologically induced organizational change *before* implementation, researchers have looked to the relationship between material artifacts and the organizations that design technologies (Bailey & Barley, 2020; Dougherty, 1992; Grant & Berry, 2011). In this category on the "design" side of the line, studies have shown a "dance of agency" between the innovators and artifact (Pickering, 1995). Material agency accounts for the "pull" of the artifact, while human agency and organizing account for a separate and distinct "pull." For evidence of change *after* implementation, we have looked to activities within the adopting organization (Bechky, 2019; Kellogg et al., 2020; Rahman & Valentine, 2021). Studies of implementation and use make up the lion's share of research on technologically induced organizational change. My contributions in this dissertation ask researchers to let go of the idea of a bifurcated field divided by a point after which a transiting technology "pulls" on the adopting organization. In a time when technological change seems to move so quickly and when information about new technologies is so easily accessed by curious organizational actors, there are only an increasing number of opportunities for future technologies to influence work and action in the present.

Experiential versus Anticipatory Change

If change begins at the adopting organization earlier than we have assumed, then we need to reconsider how we have thought about the role of the material artifact as an essential part of the change process. Thus, the second important outcome of my dissertation is that technologically induced organizational change does not rely on users' interaction with material artifacts. The contributions from my dissertation are timely in that the study of digital technologies in particular has produced more expansive understandings of materiality. Leonardi (2010) summarized that:

> …moving away from linking materiality to notions of physical substance or matter may help scholars of technology integrate their work more centrally with studies of discourse, routine, institutions and other phenomena that lie at the core of organization theory, specifically, and social theory more broadly. (p. 1)

In a case of technologically induced organizational change without access to the physical artifact, the puzzle is to understand first how people make predictions about a future technology and second how those predictions shape structure and action in the lead up to adoption and implementation.

The current model of technologically induced organizational change is an experiential one. Studies of users' experiences when interacting with new technologies have formed the basis from which we have come to understand how new technologies shape structure and action in organizations. We know that upon the arrival of a new technology—for example of a surgical technology (Beane, 2019; Edmondson et al., 2001; Sergeeva et al., 2020), an algorithmic software program (Anthony, 2018; Brayne & Christin, 2021), or a virtual platform (Bailey et al., 2012; Dodgson et al., 2013; Schultze & Orlikowski, 2010)—people try out the new technology for themselves. They use the new technology to augment existing sets of technologies still in use, or they shift to a new system entirely. Importantly, it is when people try out and begin to use the technologies that the rich set of changes scholars have documented begin to emerge, from shifts in power and status (Hinings et al., 1974; Kellogg et al., 2020; Thomas, 1994), organizational learning (Beane, 2019; Dodgson et al., 2013; Edmondson et al., 2001) and organizational routines (Howard-Grenville, 2005; Leonardi, 2011), to reconfigurations of workspaces (Barrett et al., 2012) and digital transformation (Agarwal et al., 2010). Where do we look if not to users' interactions with technologies?

Rather than expanding the scope of study to include non-experiential opportunities for change, theories developed in recent decades have enriched our understanding of what happens *around* the material artifact. One development has been a turn from material objects to the data they produce (Berman & Hirschman, 2018; Espeland & Stevens, 2008; Leonardi & Treem, 2020). New technologies produce increasingly greater quantities of data, and thus in addition to physical artifacts, recent developments in the study of information and data have expanded our understanding of the change process. Organizational researchers who focus on the instrumental and symbolic properties of data have shown that data and information often play a key role in defining the contours of an organization's informal social structure. Many early contingency theorists recognized the important role of data in determining organizational form. Scholars such as Thompson (1967), Galbraith (1973), and Tushman and Nadler (1978) all viewed the organization as an information processing entity and argued that the most appropriate form for an organization's social structure was the one that most closely matched its data processing requirements. A renewed focus on information is important to the development of a theory of technological anticipation for the simple fact that, absent the material artifact, information is all that actors have at their disposal.

In this dissertation, I looked to the ways in which people learned and talked about the future. I showed how people made sense of something they did not yet have access to and how that sense shaped the action. I showed how people gained and acted on information about the future that did not rely on the implementation of an AMI system at their agency. In Chapter 3, people organized into ad hoc groups to learn about and predict what AMI would be like for their organizations years before the selection and adoption of the technology were within reach. Because comparable organizations were already adopting AMI within the water industry, people at both agencies heard about AMI at industry conferences, from colleagues at neighboring agencies, or from consultants. They incorporated information they gathered during information seeking activities into the development of shared predictive technological frames. Those who were curious about AMI at both agencies were hopeful about the ways in which AMI would improve operations at their organizations. Fogtown's AMI group suffered an early political roadblock to their project when managers acted on fear of anti-5G activists and declined to give approval for them to move forward. The slowdown curtailed the ad hoc group's activities which nearly halted the development of their predictive frames for the technologies. Thus, the AMI future they came to anticipate themselves and share with others was more limited in application. The limited frame became important in Chapter 4 when it influenced senior managers' treating the technology as a simple infrastructure swap out rather than a shift to a new digital system that required organizational change to be successful. Data I presented in Chapter 3 also showed how Suntown's AMI enthusiasts repeatedly sought out new information and took action in ways that shaped an expansive and long-term predictive frame of major technological and organizational change ahead.

In Chapter 4 I introduced the concept of anticipatory control. While this chapter was most focused on the structural outcomes of top-down, managerial control, it introduced a new way that ideas about AMI came to bear on organizational structure. Importantly, whereas workers and mid-level managers had some degree of access to individual components of an AMI system, or had seen a system in action through a site visit, senior managers had zero interactions with physical AMI technologies. They had only their own understanding of the technology and their predictions for how they would incorporate it into the organizations for which they were responsible. For senior managers, I found that the degree to which they aligned their predictions for AMI with their other work guiding strategic planning processes was an important factor in anticipatory control.

Finally, in Chapter 5 I showed how anticipation shaped both the process and the material outcomes of selection at both agencies. Organizational changes at Suntown influenced the technical specifications that people wanted and thought they needed for both the reorganization and transition to AMI to succeed. Suntown's open RFP process enabled them to engage in a thorough customization of the components in advance of the bidding process, such that material configuration of the system they selected had already been heavily influenced by anticipatory organizing. Anticipation at Fogtown conditioned the selection process such that selectors were limited in their ability to choose among technologies and influence the material outcomes of their AMI systems.

Organizations as Anticipatory Systems

In this dissertation I presented findings about technological and organizational change that builds towards a model of organizations as anticipatory systems. The structures and processes I presented have been informed by ideas from theoretical biology (Nadin, 2010, 2016; Rosen, 2012) and developed from my analysis of the events at the organizations themselves. An approach that treats organizations as anticipatory systems, much like an approach that treats them as sociotechnical systems (Hughes, 2012; Pasmore et al., 1982), enables researchers to consider the material features of a technology while engaging with the fact that these same features are anticipated before they are implemented and used in the context of social and organizational processes. In departing from a reliance on either the "implementation line" as a starting point, or user interactions with material technologies as a focus of our study, a model of organizations as anticipatory systems changes how scholars think about technologies in organizations.

Looking to the future is an essential quality of human agency. Thus, while the data I analyzed here came exclusively from a study of two organizations in the several years leading up to and not extending beyond the selection of a new digital system, I do not mean to suggest that technological anticipation only occurs before implementation. Rather, I expect anticipatory processes to exist wherever people have agency. I designed this study to look at the years before a probable technological change because I expected that during this time period the "chordal triad" of human agency would be most weighted in the future (Emirbayer & Mische, 1998.) I showed how once people became aware of possible and probable digital futures that could affect their work and their organizations, they anticipated the future in ways that affected not only the structure and practices of their organization in the present, but informed the material configuration of the system itself. I expect that future research will uncover anticipatory organizing during implementation and use phases of technologically induced organizational change. I propose a model of organizations as anticipatory systems not as something limited to a specific period of time, but rather as a general model with which to understand the process of technologically induced organizational change. A figure of that model is below.

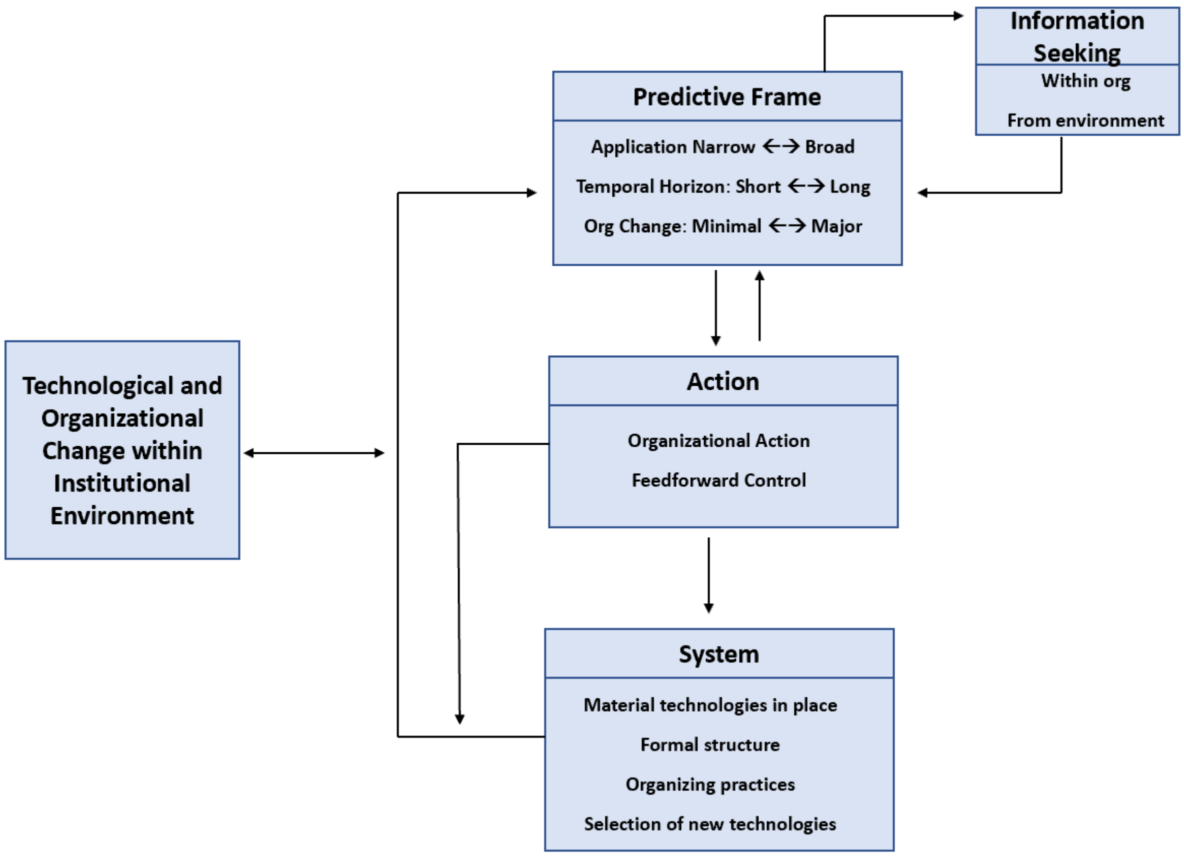


Figure 6.2. Organizations as Anticipatory Systems.

In this model people in organizations gain information about new technologies from the institutional environment. In my study, people at water agencies learned about AMI from industry conferences, other agencies, or consultants who were familiar with how the technologies were being used. Information about technologies shapes predictive frames as people begin to develop a sense that their organization may one day adopt a version of the technology they have heard about. The process of developing shared predictive frames involves further information seeking as people want to know more about what capabilities the technologies have and how this might affect work and organizing in their own organization. People hire consultants to do additional research, talk to people in other departments, or pilot versions of the technologies themselves. Predictive frames shape action. People act in ways that shape structure as well as later action. In my study I showed that they can make decisions about technologies already in place, about the structures of departments within an organization, and about who else needs to be involved in a future project. Through anticipatory control people in organizations can make significant changes to organizations that they justify with a vision of a technology about which many may have never. Information seeking or organizational action further shape predictive frames and subsequent anticipatory action. Taken together, the total effect is one of an organization that operates as an anticipatory system in an active relationship with probable futures.

Understanding organizations as anticipatory systems has at least two implications for theory about technologically induced organizational change. First is that predictive technological frames are a way that people exercise agency in the process of organizational change. The process I outlined in Chapter 3 demonstrates two distinct ways that people perceived a future technology and began to act. Their actions were consequential in that they conditioned the way in which *others* in their organizations perceived the future and took action. This is important because while we have developed theories about how people construct frames about what a technology is and what it is to be used for (Davidson, 2002; Mishra & Agarwal, 2010; Orlikowski & Gash, 1994), an anticipatory systems model incorporates the fact that predictive frames can begin to shape work and organizing once people only *hear* about a potential new technology. Without having access to the material technology, the number of ways in which people can imagine its future uses has the potential to be much greater than what they would come up with through interaction.

Anticipation unites expectation and action. This means that when people develop shared frames about how broadly the technologies will be applied, the degree to which the organization will restructure with the technologies' arrival, and how far in the future the change process will occur, they begin to act in ways that are informed by their future outlook. As I showed in this dissertation, predictive frames can shape not only organizing, but also what material technology an organization will eventually adopt. Thus, the study of technologically induced organizational change must account for the influence of probable and expected futures on structure and action in the present by assessing what predictions are taking root and how people incorporate them into organizing. Taken as part of an overall model, analyzing the role of predictive frames requires scholars to model the future as a sociomaterial phenomenon. How people understand the future is an important and consequential factor in the process of technologically induced organizational change.

The second implication is that anticipation may alternately expand and limit the horizon of possibilities for how new technologies will shape *future* work and organizing. As an antecedent to implementation, there is potential for anticipation to shape much of what we know about technologically induced organizational change. This is important to consider because my study did not address the consequences of anticipation for implementation and use. There were two reasons for this. The first and most apparent was methodological. This study was based on three years of data collection, and to include implementation and use would have required at least another two years. Once I realized that there was something important happening in the data I collected over those three years, I was able to justify ceasing its collection for the sake of analysis. This leads the second and more important reason for omitting implementation and use, which was theoretical. I wanted to analyze anticipation as a standalone phenomenon that did not require explanations of what came after to be meaningful. The consequences of early anticipation for implementation and use are, however, also deeply important.

I analyzed the process of anticipation up until selection, but one can already speculate how the organizations will incorporate their AMI systems based on what we have seen so far. Suntown's Water Division was poised to push integration among departments within the division, but also with other departments within the larger municipal organization. In one of my last interviews with Suntown's director, George, he expressed a desire to "take over the finance department." Through his anticipatory involvement with AMI he had learned that many of his plans for the technology and its data depended on a close integration with the billing department, but he was repeatedly frustrated with their reluctance to get more involved. The broad way in which Suntown anticipated the application of AMI may break down divisions (or "siloes") among departments in the Water Division in the future, but it could also lead to more entrenched separation between the division and the rest of the city if they come to work with data and technology in wholly different ways. Furthermore, if George has his wish and takes over the finance department so as to get more out of AMI, he will likely confront new kinds of data and occupational challenges during the process of departmental integration. Fogtown's experience is likely to be very different from Suntown's. As a project that barely made it over the finish line and that did not enjoy the support of senior management, it seems unlikely that its supporters will have either the inclination or the power to enact broad organizational changes to best take advantage of the new system. Thus, understanding the way in which people anticipate new technologies is an important part of building theory about processes that occur later. Scholars may find that anticipation helps unravel theoretical puzzles about technologically induced organizational change. By incorporating anticipation into our analyses, we can better explain both how past experiences shaped the present, but also how the future becomes implicated in the present-tense experience of technological change. As scholars, we cannot understand why the ending of something was what it was without a better sense of its beginning. Anticipation helps to explain that beginning.

What Anticipation Means for the Study of Temporality and Planning in Organizations

Temporality in Organizations. In proposing a model of organizations as anticipatory systems, my dissertation contributes both a structure and a process to aid in our understanding of temporality in organizations. That the demand for greater attention to temporality reappears in the organizational literature with some degree of regularity (Ancona et al., 2001; Asgari, 2020; Oborn & Barrett, 2021; Orlikowski & Yates, 2002) suggests that Barley (1988) was correct in his observation that "[a]side from the allocation of activities to space, nothing anchors patterns of work more securely than the timing of action" (p. 125). Anticipation contributes to the study of temporality in two ways. First, anticipation is a specific *experience* of time. Research on time in organizations have found that in some contexts people can feel that time is an external, objective[13] reality over which they have no control (i.e., the number of hours in a day or the duration of a commute), while in other contexts time can be experienced more subjectively (i.e., rearranging schedules to go on vacation) (Ancona et al., 2001). E. P. Thompson's (1967) work on "cultural" versus "task orientation" time demonstrates another example of consequential differences in categorical perceptions of time.

[13] The most common division of temporal experiences is of time's subjective and objective qualities (Orlikowski & Yates, 2002). Barley (1988) has made the point in a footnote that the descriptors "internal" and "external" are more appropriate, as the subjective/objective binary "suggests an ontological distinction that ultimately fails" (p. 163).

In this dissertation I have shown that anticipation is form of action that is shaped by predictions of probable futures. This idea helps researchers bridge the experiences of external and subjective time. For example, actors can perceive a future event as an external reality, but through anticipation they can incorporate it into anticipatory action such that they establish agency in relation to that external event. Anticipation is a way in which actors experience the future. For example, an IT director at a firm that will soon undergo a merger may anticipate the event by networking with other senior managers so as to secure his or her position in the future firm structure. More than bridging external and subjective time, through anticipation an actor can *shape what future eventually comes about*. The predictions that informed the IT director may shape action in such a way that his or her colleagues come to share the same predictions about leadership roles in the future. If time can be experienced in different ways, for example the experience of time-use as dedication, performance, identity, and power (Feldman et al., 2020), then anticipation helps enrich our understanding of the experiences of time by showing how the prediction of future events informs action and time-use in the present as a linked external and subjective temporal process.

A second contribution to the study of temporality is the idea that anticipation is a *structure* of time. Like all structures, time can enable as well as constrain (Giddens, 1984; Orlikowski & Yates, 2002). For example, temporal structuring in organizations is a means through which managers may exercise power and control through the enforcement of subjective deadlines and the boundaries of the workday as structural constraints (Nandhakumar & Jones, 2001; Saunders et al., 2004). For example, the way in which managers structure time is an important factor in achieving ambidexterity and balancing out exploration and exploitation (Mathias et al., 2018). The structure of time can also provide a sense of meaning, as with a shared experience of rest on the weekends or the stress of the end of the fiscal year (Mazmanian & Beckman, 2018). I have shown in this dissertation that an anticipatory structure of time is one in which the nature of future predictions (their horizons, breadth of application, and implied need for organizational change) are important facets in organizational change. Anticipation is a way that people can manipulate structures of time. Understanding how anticipation is at work in organizations can shed new light on the organizational activity affected by different temporal "frameworks" (Barley, 1988). As I showed in Chapter 3 of this dissertation, people developed predictions that differed greatly in terms of the horizons of change. Furthermore, in Chapter 4, I showed that senior managers can bring about significant organizational change based on the way in which they structure the needs of future events in the present. The organizational and infrastructural change that mangers brought about was a form of temporal structuring in that both were couched in future events and their link to the present.

That people can manipulate structures and perceptions of time is essential to its importance in the sociological literature. If time were purely an objective force it would be of little interest to social scientists. People in organizations think about the future and participate in its construction through work. Different temporal frameworks within an organization can cause conflict. Oborn and Barrett (2021) found that occupations in hospitals with conflicting temporal orientations can experience difficulties in coordination as a consequence of resource conflict and strain. They found a change for resolution in human agency over subjective time, however, in their finding that "with some effort, occupational members may productively resource temporal orientations in developing solutions to challenges in work coordination" (p. 377). Thus, through anticipation people can manipulate time in the same way that people can manipulate structure, such that "in the process of temporal structuring, every human action constitutes, is constituted by, and can potentially reconstitute the temporal structures being enacted" (Orlikowski & Yates, 2002, p. 689). Through anticipatory action and the mechanism of surrogate time modeling and feedforward control, people in organizations exercise great agency over the structure of time in the present. There are a few mechanisms that disrupt the direction of time's arrow to include the future within reach of the present.

The Role of the Future in Planning. I have shown in this dissertation that by theorizing organizations as anticipatory systems we better understand the role of prediction in planning, and also how important aspects of planning take place outside of formal planning activities. The future is important to planning because planning involves prediction. One way that organizations incorporate the future into planning is through what Flyverbom and Garsten (2021) have called "temporal reorganization," which is a means by which actors understand different futures. Futures that are perceived as much further away allow for more creative and fantastic planning as planners imagine how the world around their organization will have changed in the distant future. Futures that are closer to the present, they argue, require more practical approaches. Their argument essentially outlines how there are many different ways to envision the future, and that power over future projections is a form of consequential knowledge production, such that anticipation has "organizing effects" in the present (p. 2). Traditionally, managers work with analysts to analyze and organize information to produce predictions and related plans for possible crises, shortfalls, or bumper years.

A theory of organizational anticipation offers a specific process through which actors both develop and act on predictions of the future, which includes information seeking, organizational action, surrogate time modeling, and feedforward control. In Chapter 5 I show how these processes affect the materiality of technology during selection, but they could also affect outcomes in the related practices of hiring (Hong, 2020; Sinha & Thaly, 2013; van den Broek et al., 2021), which is the selection of new employees instead of material technologies, or of mergers and acquisitions (Haleblian et al., 2009; Santos & Eisenhardt, 2009), which shares commonalities with a procurement process.

Contingency planning has been the means by which organizations can take stock of their operations and world around them and assess how variables internal to the organization or external from the environment may disrupt their core functions. Studies of types of planning like contingency planning, strategic planning (Ketokivi & Castañer, 2004), or crisis management (Smith, 1990) center more on the preparation work than the prediction itself. By design, contingency planning can give equal weights to many predicted scenarios because the more scenarios considered, the better prepared the organization (Perrow, 1967). In moving from planning to anticipation, organizations will come to accept one prediction as most probable, such that it begins to inform action in advance to the predicted future state. In Chapters 3 and 4, I have shown that many predictive activities take place outside of formal planning processes. Informal conversations at work or encounters with colleagues from other firms are sites in which predictions are shaped and thus are greatly influential to the ways in which plans develop and are accepted by others. In Chapter 4 I show specifically how workers' activities related to language, positioning, and the role of the champion are major influences to planning processes conducted by senior managers behind closed doors. Thus, organizational anticipation shows us that it is important to understand how it happens that one prediction becomes understood as probable by people in a group or a particular occupation within an organization.

Conclusion

New technologies are often bound up with discussions of the future of work in both research and broader culture. This study was always partially inspired by David Noble's insistence on the need for the study of "present-tense technology" (Noble, 1995.) Noble argued that technological change was often justified by its future benefits, which could distract both workers and scholars alike from their effects in the here and now. A model of organizations as anticipatory systems gives some scaffolding to his claim. My hope with this dissertation is that a theory of technological anticipation helps us to better understand how our expectations of the future are not just ideas in our heads, but instead are modes of perception that are both meaningful and consequential for technology, work, and organizing. What I have found shows that limits to our predictive imaginations may also limit our ability to benefit from new technologies once they are implemented and in regular use.

The potential impacts of technological anticipation for both organizations and society are profound. One way I learned this from this dissertation was through studying new water management technologies in context of an unprecedented drought in the Western United States. Where water is a precious and increasingly scarce resource, the technical ability to track it at a more granular level can better enable its conservation if used in an expansive and integrated way. In coming to an end of this dissertation, I return to one of my more existential conversations about AMI with Jeff, a conservation analyst at Suntown:

> As a parent of two little ones, I think about the drought a lot. The climate models we looked at when I was in college were saying we'd start to experience the effects in 2050, but we are experiencing them now. There are frequent "extreme" weather events that are affecting a lot of people already. And we shouldn't *not* do anything! People may have lost hope, but small changes can lead to big changes collectively. Technology is important for this. We need the consumption data to see where the water is going. With more data comes a higher level of responsibility. There was always a fair amount of room for error with monthly or even bimonthly reads. My hope is that in the future we will be able to provide data to manage our water use together.

Jeff described a future where technology would enable him to work in a water agency that could ensure his children's future during climate change. His hopes for AMI are important because new technologies have historically served as a cultural repository of human hopes and anxieties about the future (Bix, 2000). I hope that with this dissertation, I have helped show how hopes, predictions, and expectations are an important part of life and work in the present tense. Understanding the implications of anticipation is part of the larger project of ensuring that technological change improves both work and life on a fragile and changing planet.

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Appendix I. Technical Background on Metering Systems

Mechanical, AMR, touch, and AMI Metering systems

The purpose of all metering systems is to measure, capture, report, and bill for water use over a billing cycle. The process of capturing reads and producing utility bills was often referred to as the "meter to cash" process. Traditionally, systems were made up of ***mechanical meters*** and meter registers that human meter readers visually checked on a monthly or bimonthly schedule. Meter readers digitized analog data from the meters by inputting reads into a handheld device. The data from meters was then manually verified in the meter shop and billed by a utility's billing department. In recent decades many utilities have upgraded their metering infrastructure to automate some of the steps in the metering process. As they upgrade their systems, utilities have the option to build new technical capabilities into the system.

One shift in metering was to either automate and ease the process of gathering monthly reads. One widely adopted system was called "drive by" systems, or ***Automated Meter Reading (AMR)***. AMR systems upgraded fully mechanical systems by affixing a small radio transponder (widely referred to in the industry as an "endpoint" or "MXU") to be meter body. The transponder converted the analog signal from the mechanical meter, or read a digital signal on a digital meter, and broadcast it on demand to a nearby collector unit. Meter readers could either walk the route without stopping, or collect reads from their vehicle. Some cities installed 100% AMR meters, while others prioritized dangerous or hard to reach meters for a switch to AMR. A similar but not widely adopted system was a ***touch*** system. Touch systems involved installing a transponder to the outside of the meter box that could transmit the read to a collector attached to a wand. This allowed meter readers to walk routes more easily because it saved them the work of bending over, opening a meter box, digging out dirt left by gophers, and visually reading a meter register. Both AMR and touch systems produce one volumetric read per month.

New systems, called Advanced Metering Infrastructure (AMI) capture both a higher quantity and variety of data at the meter, transmit it back to the utility over one of many different types of networks, and analyze and report on the captured data in different ways. Because there are many kinds of technologies on offer for each component of an AMI system, a utility beginning the process will find that they can customize their AMI system in many ways. One utility may want to build an AMI system that can not only automatically capture hourly volumetric reads, but also measure temperature or pressure and perform remote valve shutoffs. Whatever information collected by an AMI system must be transmitted over a network to central "data collector units," or DCUs, mounted on telephone poles across a service area. A site's topography will determine what kinds of networks, either cellular or radio, can reliable transmit data from every water customer. The type and quantity of data one AMI system can produce and process varies greatly from one utility to the next. For water utilities the transition from tradition meter reading to AMI requires a reconfiguration of the many interconnected components of a traditional meter reading system. A comparison between traditional and advanced systems reveals the many choices utilities have to make about each component, the infrastructure that supports it, and the data outputs it can produce. Figure A.1 shows a visual comparison of traditional and advanced metering infrastructure:

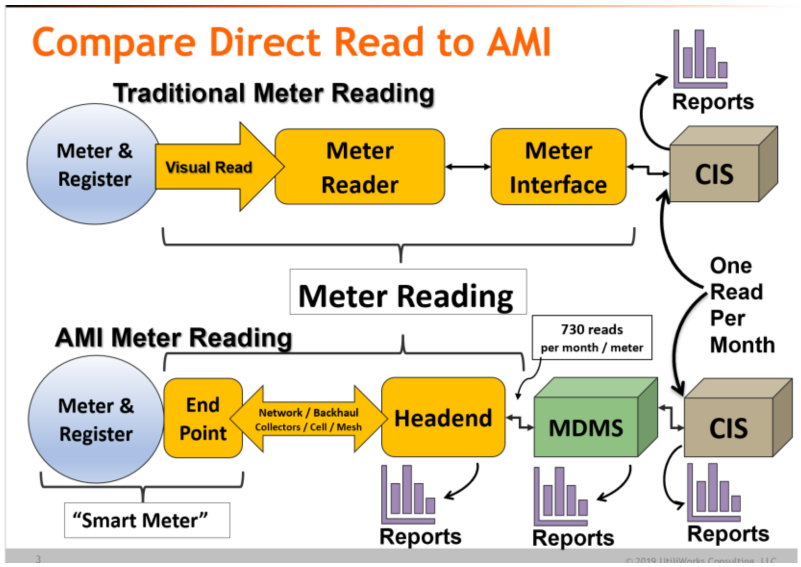

Figure A.1. Traditional and Advanced Metering Infrastructure.

Measuring volume with meters and registers. Any commercially available meter can be used in either traditional or advanced metering infrastructure. All meters measure the volume of water that passes from one side of the meter to the other. The ways in which meters measure volume varies, but each measures volume and displays this information on a register that sits on top of the meter. This means that traditional meters can be used in AMI systems with the attachment of an endpoint, which I describe in a subsequent section.

Positive displacement meters. As water flows through the meter to the customer's pipes, a disc inside a precision chamber within the meter nutates (or wobbles) in response to volumetric pressure. Water physically displaces the disc in proportion to the amount of water that passes through the meter. The precise cycles of the nutating disc mechanically measured water on the meter's register by a tenth of a cubic foot. Because the meter is mechanical, if a "backflow event" occurs, such that water flows from the property backwards through the meter and into the City's pipes, the meter itself well go backwards. Like an odometer, a register on top of the meter has dials that rotate to indicate volume. The register is read visually by a meter reader who opens the meter box, flips up the plastic cap on the register and punches in the current volumetric "read" in a digital, handheld device. Registers can be either analog or converted to a digital display, as shown in the two figures below. Meter readers typically prefer reading mechanical registers, as they are built to be read at a glance. The important lower resolution numbers that are billed (i.e., if the utility bills in hundreds of cubic feet, the meter reader wants to quickly discern hundred cubic feet only) displayed with a different background. Meter readers report that digital registers are difficult to see in the sun, or that their plastic protectors get easily scraped by sand a dirt over time, making them more difficult to see.

Figure A.2. Mechanical Water Meter Register.

Figure A.3. Digital Water Meter Register.

Velocity Meters. Velocity meters measure water's volume by deducing it from its volumetric flow rate. The volume flow rate describes how much matter moves through space per unit time, which is measured in a physical dimension such as volume, rather than mass. Volume flow rate can be used for liquids and gas, but not for solids as they do physically flow in the same way that gases or liquids do. For example, when a water customer runs a garden hose, a given number of gallons of water passes out of the end of the hose in a given amount of time (usually seconds or minutes). This amount is considered the volume flow rate. We can summarize this process in a simple physics equation. Volumetric flow, expressed as Q, is the product of a cross sectional area (A) and the average flow velocity (v) such that Q = AV. The area is a fixed number depending on the size of the pipe on which the meter is placed.

There are two ways to determine velocity: the Doppler effect, or "transit time". Both methods rely on the use of ultrasonic waves within the water meter. Doppler meters use a transducer to emit an ultrasonic beam into the water stream flowing through the pipe. The ultrasonic beam bounces off bubbles or solid particles in the flow of water, and as the bubbles and particles shift the frequency of the beam, a second transducer reads the change in frequency. The change of frequency indicates the velocity at both the first and second transmitter. Transit Time meters which measure the amount of time required for the ultrasonic signal to pass between 2 or more fixed points inside the meter.

Utilities may choose to install ultrasonic water meters because they can be very accurate down to even very small volumes of water. Residential meters are capable of measuring down to 0.01 gallons or 0.001 cubic feet. Ultrasonic meters can emit either and analog or digital signal to the register.

Traditional meters' valves have only two points: open or closed. When an account is past due, or when a water customer moves in or out, a meter reader must "roll a truck" to visit the meter of that account holder. For nonpayment, up until recently the meter reader would close the meter valve and lock it with a small padlock until the customer pays the bill. After bill payment, a meter reader visits the meter once again to unlock and open the valve and allow water to flow onto the property. When a customer moves in or our, the meter reader visits the meter to get a final read, which is sent to the billing office. Customers moving out are issued final bills, and customers moving in are billed for water used after the water has been turned on.

In some advanced meters, the meter is equipped with a remote controlled valve which utilities can use for remote connecting or disconnecting of water service, or even reduction of water flow to a minimum. New state regulation in California is coming into effect that prohibits full shutoff of water in the case of nonpayment, and some utilities are moving towards meters that have partial shut off capacity. The idea is that the customers do have access to enough water to drink, but they will be motivated to pay their bill because the low flow does not allow for bathing, clothes or dishwashing.

Endpoints (also Meter Transmitting Units "MTUs" or "MXUs") The purpose of an endpoint is the capture data from the meter and transmit it over a network to the utility. Traditional metering systems do not have endpoints, as the information from the meter is not stored anywhere besides the register and is captured visually by meter reading staff who physically visit each meter and input the volumetric read into a handheld device. AMR, touch, and AMI systems all rely on the endpoint to transmit volumetric data in addition to other data the meter may collect, including temperature, pressure, and tamper alerts.

Endpoints enable a greater degree of data collection and reporting than a register alone. Whereas registers can communicate only one volumetric datapoint at the time of a reading, endpoints can store many data points in many different categories. Endpoints can be attached either by splicing to the register and sealed with a waterproof gel cap, or attached with a connector like the one shown in the figure below:

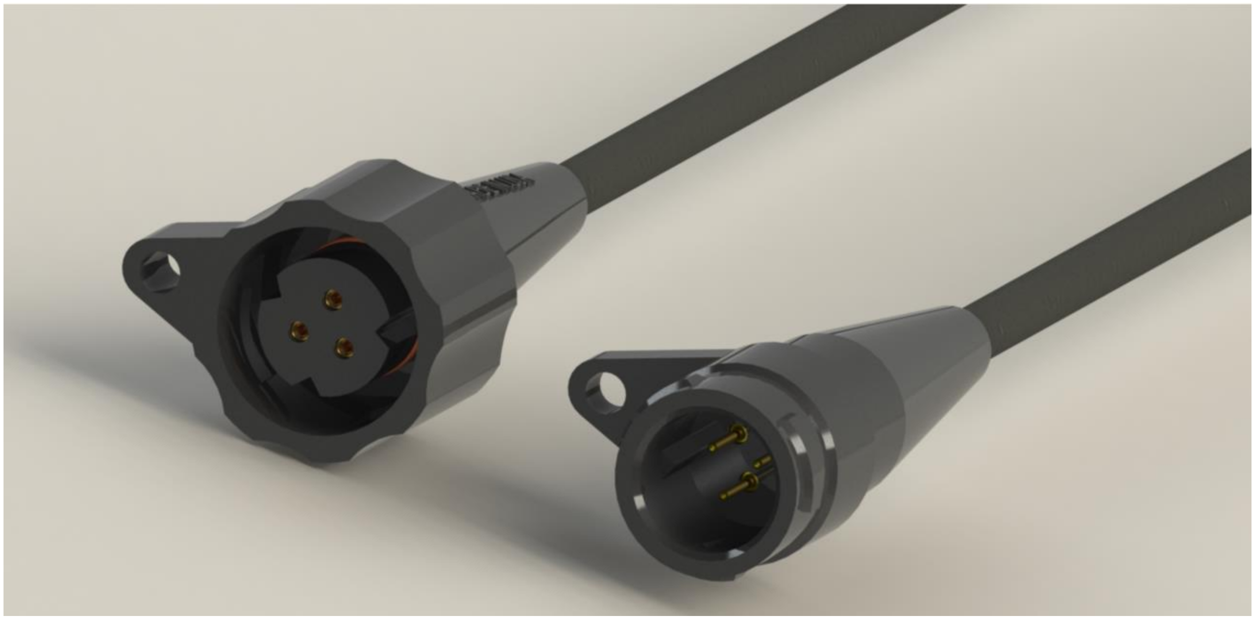

Figure A.4. Endpoint Connection.

Meters can input either analog or digital data to endpoints, where those data are stored and then transmitted to the utility. Some affordances of endpoints include:

- Configurable interval reads - typically hourly for water
- Meter endpoint data repository - typically 35 days or more of data
- Meter endpoint reverse flow and leak detection, tamper and theft detection communication
- Remote firmware upgrade via RF
- Event logging
- On-demand readings
- Remote disconnect (if meter has)

Networks

Data from meters are transmitted over a network. There are two broad categories of networks that utilities can build, and within each category there are still further differences between the types of technologies. A network can be based in either cellular or radio technology. Before deciding on what kind of network to build, cities request propagation studies from prospective bidders. Propagation studies assess coverage rates and what kinds of infrastructure components are needed to have full coverage with a certain degree of redundancy. Cellular propagation studies rely on the already-built cellular infrastructure in place. Radio propagation studies require the installation of both Data Collector Units (DCUs) that “hear” the signal from the endpoint over a given radio frequency. Below is a figure of a DCU for a radio network proposed in this study:

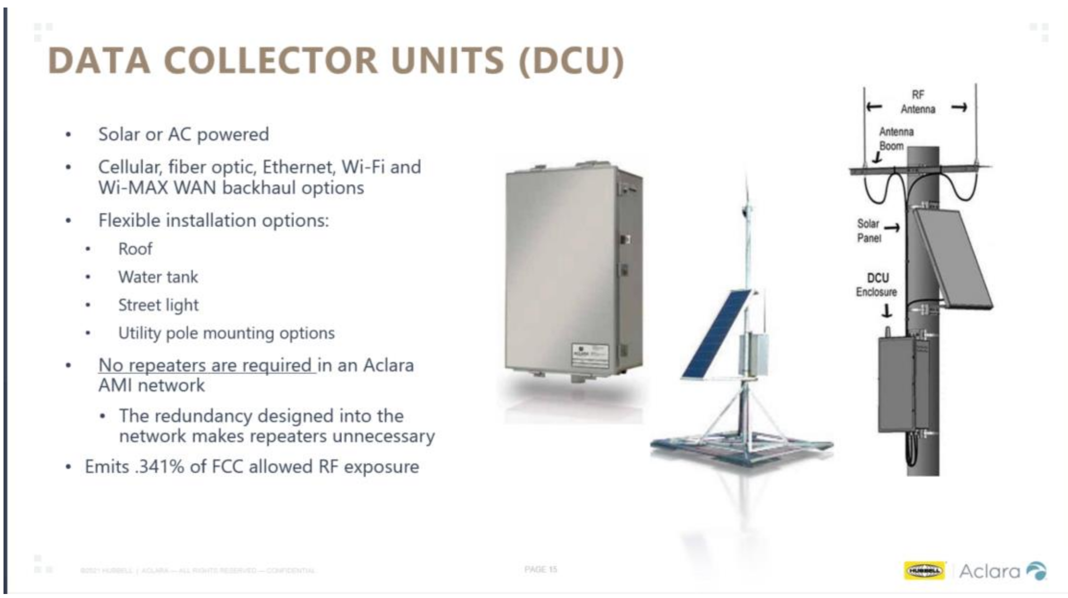

Figure A.5. Radio Network Data Collector Unit (DCU).

The figure above makes a note that “no repeaters are required”. Repeaters are small, box-shaped devices that can be installed around a service area that strengthen or extend the network made possible by DCUs. Some cities do not want to install repeaters because they make up an additional physical device that must be approved by an Architectural Review Board. Some cities have strict review boards that try to limit the amount of hardware installed on street lights, telephone poles, or other assets in the city. The amount of DCUs proposed in network propagation studies depends on both the area’s topography and the strength of the radio signal. Stronger radio signals can go farther, which makes it possible to install fewer DCUs. For the site in this study proposals ranged from 4 to 22 DCUs.

AMI systems that transmit over radio can use either licensed or unlicensed bands as regulated by the Federal Communications Commission (FCC). A small number of companies that build networks for utility AMI systems have purchased licensed bands, such as proprietary bands that were used by pager companies in the past, and promote the license heavily as a sales strategy to utilities. Licensed bands have the advantage of being uncluttered by other users' traffic, thus requiring less power to transmit data. The figure below is from a company's promotion of the benefits of a licensed band network:

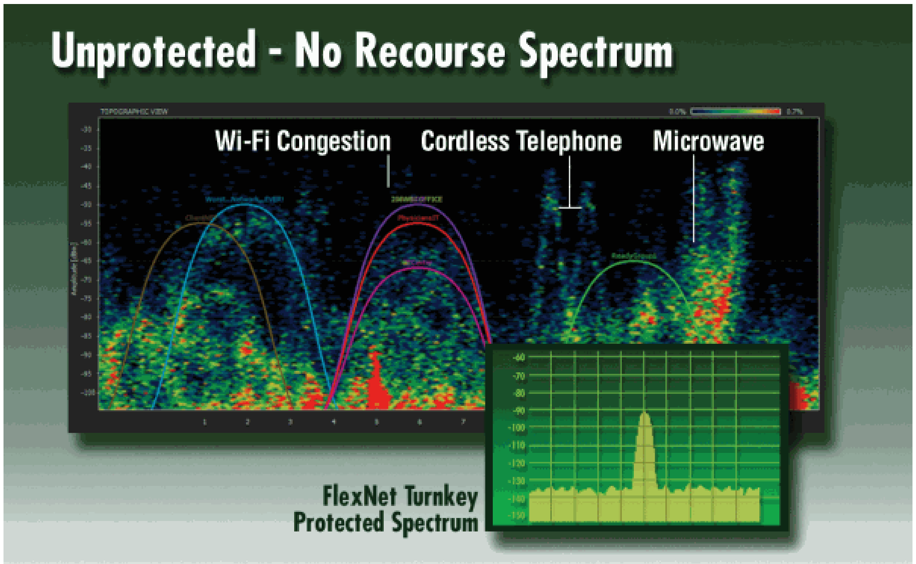

Figure A.6. Traffic on Unlicensed vs. Licensed Radio Bands.

The figure of the unlicensed bands show activity from various devices at once, while the "protected spectrum" allows for only a single data communication.

Licensed bands vary in strength. This variable means that a network built on a licensed band of 450 megahertz will require more DCUs than one that transmits at 900 megahertz. During a shortlist interview at Suntown, a company representative compared his firm's 450 megahertz band to competitors' in the field:

> I understand there is a licensed 900 megahertz solution being proposed, which in most cases is going to propose fewer collectors than ours. But the problem there is with a smaller number of covering the wider area, you're going to lose redundancy. So we are sacrificing having fewer collectors for having that peace of mind that you're going to have some adjacent coverage in the case you get a battery or a mechanical failure.

The representative made the case that their network is more reliable because it has more built-in redundancy. Their propagation study advertised triple redundancy for about 98% of the MTUs in the field, which means that any DCU that fails could be temporarily covered by nearby DCUs until a repair is possible. The competitor's 900 megahertz network required only four DCUs for the same service area. While city representatives liked the idea of having to get fewer DCUs approved by the notoriously stringent Suntown Architectural Review Board, they were generally skeptical that four units was enough. The sales rep further explained:

> I believe we are the only vendor that the city is considering for this project that operates in that 454 City licensed band. The advantages are that we can transmit a more powerful signal greater distances while maintaining battery power. Some of our competitors have different technology that requires more infrastructure or a more powerful signal that may impede the battery life of the device.

This quote shows that the sales rep is trying to position their band as being "just right" as positioned between a higher power licensed band and an unlicensed band. Higher power bands require less built infrastructure but may suffer from less redundancy, while unlicensed bands require more power to get through the "noise", which will drain the batteries on the MTUs.

In comparison, the owners of the more powerful 900 megahertz band pitched its advantages to the city in this way:

> We really realized that to be successful in a fixed network environment, we needed to own the FCC spectrum. We had to really be the primary holder of that license. Previous to that we had engineered a unlicensed fixed based system, and we were just getting noise all over the place and we knew that there was really no way for us to protect ourselves against that noise. We were just going to end up crafting to put more collectors up, right, which is never enough that's just not something that you know you can reliably operate in. So we knew we had to get a licensed frequency. We purchased the primary license frequency for the nation on all of the old paging networks, not too many people are walking around with pagers on their belts anymore. We actually acquired that spectrum from the paging companies. At that time, so we owned roughly 525 kilohertz of spectrum at the time. Nationwide, we lease, those licenses to our flex net customers, free of charge. The SEC requires that even though we own license and you're an operator license. We still need to provide you a lease operate that license. And that really are to ensure that if our company were to ever go under and not exist as a company, then you become the owner operator of that license within your service territory for the remainder of the product life. You can retain the license for yourself.

The company representative characterized their licensed band as more reliable for the long term because he knows that utilities generally procure technology with an eye on the distant future. Utilities want to have a sense of how they will use a technology in 20 or even 100 years long after the company that sold it to them is gone.

Firms that build networks on unlicensed bands are competitive in the AMI market. Devices that communicate on unlicensed use one of the bands set aside by the FCC for industrial, scientific or medical (ISM) applications. ISM bands have limits on the amount of power than can be transmitted. transmit 1 watt or less of power, not cause harmful interference and accept any interference received without causing undesired operation. Unlicensed bands are wider than licensed ones, and devices use what is called a "chirp spread" spectrum to communicate above the noise. Chirp spread spectrum uses the entire available bandwidth to broadcast a signal, enabling it to communicate despite channel noise. This approach to communication over wide, shared bands is called LoRa, or "Long Range". Devices can modify their pitch to differentiate the signal against the rest of the signals present on the band. A sale representative from a company deploying a fixed, unlicensed network compared it to how animals communicate with each other in the crowded jungle:

> An unlicensed network is like sitting in a crowded bar and your friends all talk at the same time. You can probably hear the person next to you and the person next to them. Then you have a lot of ambient noise in that bar and you can't hear people any further away from you. You can't read lips. What LoRa does is it drops that noise floor by using frequency shifting and frequency modulation spread. It's like a jungle. Jungles are inherently noisy. All the different animals are talking at the same time, but parrots and bugs can still find each other. And it's because they can recognize the pattern of the signal. In radio, this principle allows you to cut through the noise floor that's in the environment so you can get a good read. This is how we increase that distance, similar to a licensed network, with LoRa modulation. This is a good thing.

Sales reps like the one quoted above describe the LoRa "language" as more reliable than fixed bands as a function of the much wider band area for communication. A wider band is like a wider pipe, they explain, with greater capacity for data transmission. Narrow bandwidth fixed frequencies, on the other hand, are like narrow pipes that can limit the size of data transmissions.

Cellular networks require each meter endpoint to have a sim card installed. Sim cards are identical to those used in cellphones, and they are proprietary to a cellphone company like AT&T or Verizon. Data is sent over the cell network, which relies on cell phone towers built and maintained by cellular companies. The network coverage of a meter cell network is dependent on the tower infrastructure that a cellular company has built in a given area. If a utility operates in a town with known "deadzones", for example, they can expect the same coverage problems for their meters that residents may experience with their cell phones at a given address. To overcome network

Most radio and cellular networks are built to have MTUs communicate directly to DCUs. It is possible for either network, however, to operate as a "mesh" network. A mesh network is like another layer of communication in which MTUs can communicate with each other. Data can be passed from MTU to MTU directly. This means that if a DCU were to fail, MTUs could activate to send data from the meter along other MTUs until they reach the communication area of another DCUs. Mesh networks use more battery power, and thus require utilities to schedule more frequent battery changeouts at each meter. Mesh networks are popular for cities that want to build support for the Internet of Things (IoT) that often fall under the wider umbrella of “Smart Cities”.

Finally, any radio network can either be owned and managed by the utility, or can be procured as a “managed” network, or “Network as a Service (NAAS).

Software

Once meters, endpoints, and network infrastructure are in place to transfer data from the meter, several interconnected types of software capture and manage those data streams. The purpose of software is to capture, store, validate, and analyze data. While the boundaries between different software systems vary from vendor to vendor, the general flow is for data to first go to an AMI Headend system, then to a Meter Data Management System (MDMS), which sends a portion of processed data to a Customer Engagement Portal (CEP). All of these systems interact with a utility’s billing software. In the diagram below, the Headend and MDMS are collapsed into the company’s “Aclara One” software as a single entity, but it also shows data being transferred as either “flat files” or Application Planning Interfaces (APIs). between the utility’s CIS billing software and the CEP (called ACE in this diagram).

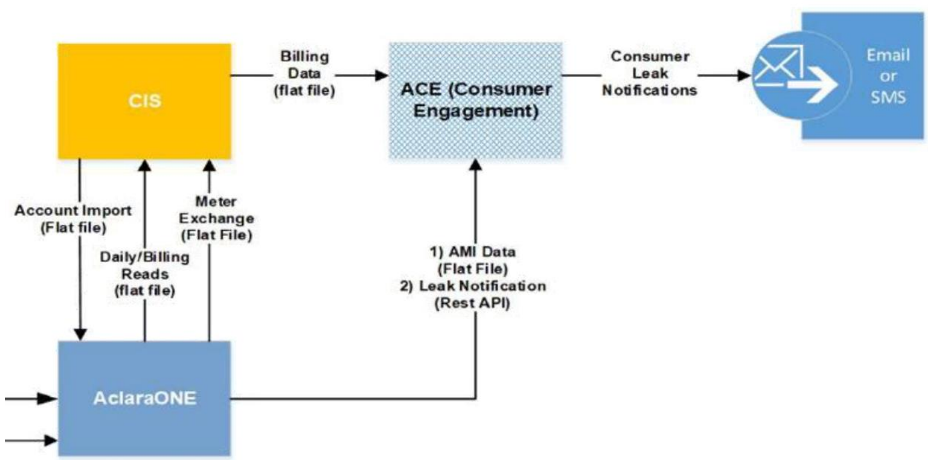

Figure A.7. General Flow of Data.

Headend systems

Headend software is the first software that captures and validates data from meters. One company’s representative summed it up this software when he explained that “Anything related to the network management piece really is what you get with the headend.” It is with this software the users will monitor MTUs, DCUs, and repeaters, and because its purpose if for network maintenance, headend systems are usually relatively limited in data analytics capacity and is reserved for only a handful of users at a utility to access. The figure below shows these components connected together:

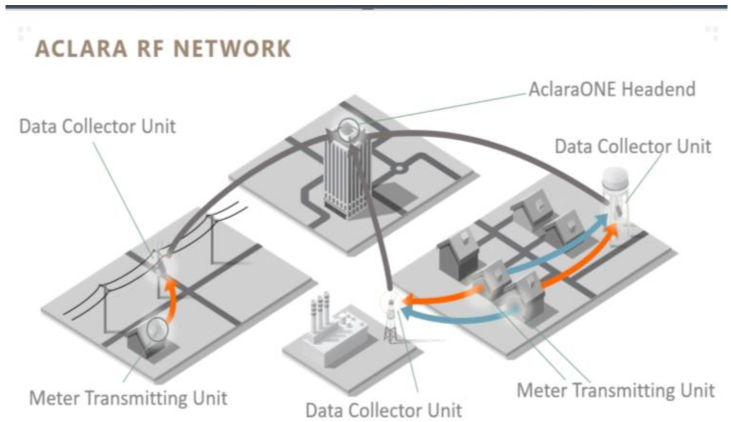

Figure A.8. Headend Connections.

Most utility staff will want to work with the various forms of interval data from the AMI system, which is handled in more depth by the MDMS software downstream from the headend system. Headend systems capture all data from MTUs, perform a basic validation on the data, and then transfer all of that data to the more advanced MDMS. There is two way communication between the MTUs and the headend, such that the headend can “ping” the meter for a read in between regular data transmissions from the MTU to the headend. The utility staff person who wants to ping the MTU for an instant read does not access the headend, however, but rather executes the command through the integrated billing system or MDMS, which they have access to. Functionally, however, it is the headend that communicates directly with the MTU. One provider explained it in this way:

> When the meter starts to communicate to the AMI headend it also starts to push data to the AMI headend. And depending on the AMI headend, we can have data coming in at a frequency that’s maybe once a day, or it could be multiple times a day. So historically, it was once a day, these days, we see instances where AMI systems are gathering data six to eight times a day.

As with most software in AMI systems, headend software can be hosted locally by the utility or on a secure cloud service like Microsoft’s Azure or Amazon Web Services. The figure below shows a proposed radio network’s MTUs and DCUs communicating with a central Headend system. The figures below are two examples of the kind of information that a headend system will display:

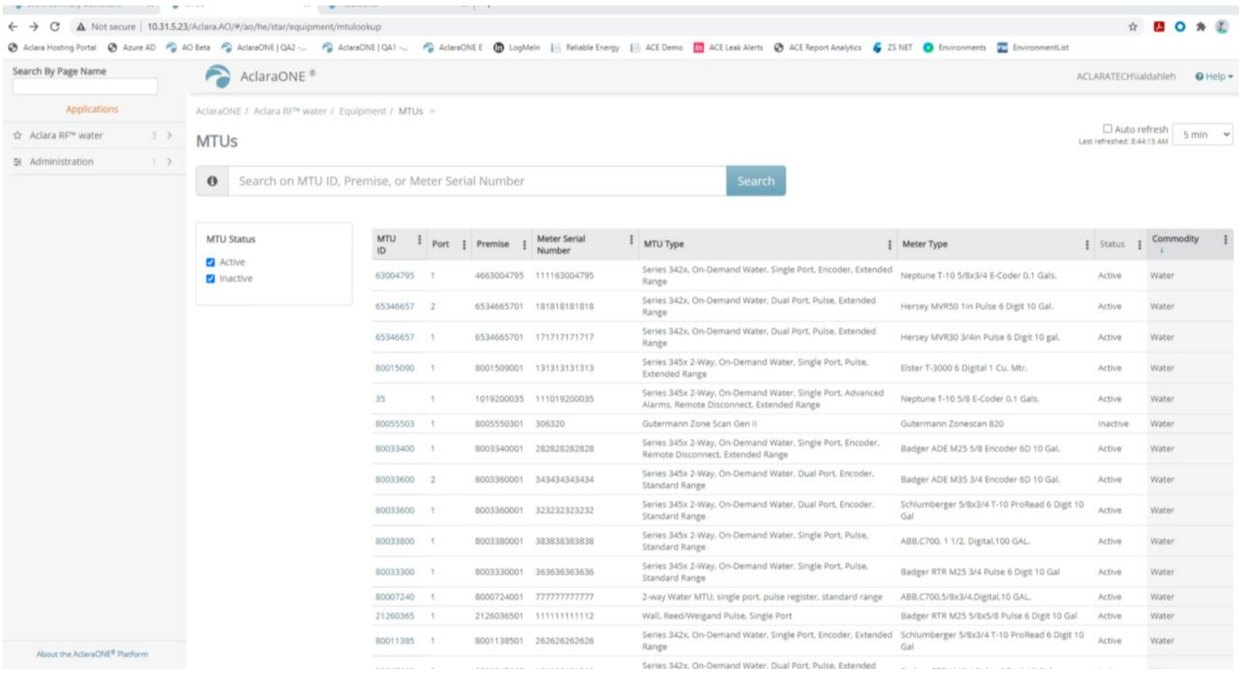

Figure A.9. Headend Software Display for Meters and Mtus.

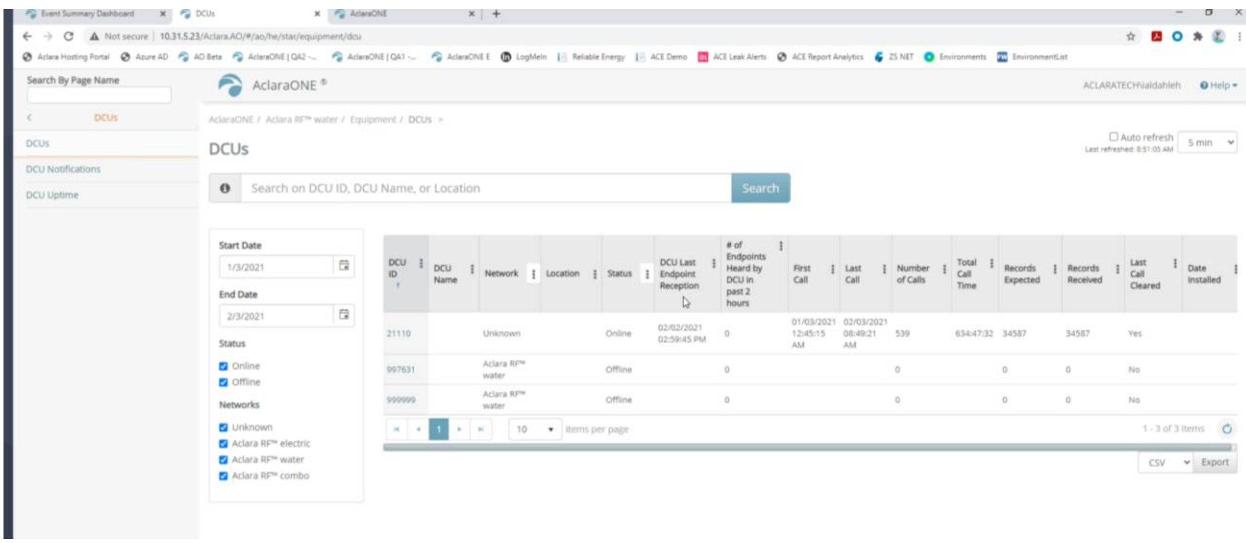

Figure A.10. Headend DCU Monitor.

In this browser-based software interface, a user can check on the status of individual network components such as meters, location ("premise"), serial numbers, MTU types, and so on. A user could also check when the next scheduled read is to occur, and a limited history of historical data from the total service area. Headend systems will perform basic validation of reads by checking them against historical usage and deduping repeat data.

HOW THE HEADENDAND MDMS TALK TO EACH OTHER

The boundary between the headend and the MDM is fluid, and each company will enable different analytics between the headend and MDM. A simple way to delineate is that the headend is for managing network infrastructure and performing initial, basic validation and the MDM is built for extensive and diverse analytics. A software rep from one company explained the tightly coupled headend and MDMS systems:

> The headend really needs to get the traffic from the MTUs and then pass it on to the MDM. So if you want to diagnose a certain MTU or a lot of the functionalities is actually sitting in the MDM. For example the "events dashboard" that you'll use every day is part of the MDM because all of the analytics is actually sitting there. So for you to walk through and having utility roles, customer service reps looking at account searches, you know, looking at the data analyzing the data in terms of different consumption based analytics, continuous consumption and all that other stuff, all the metrics, it's all saying in the end. , the only thing that's seeing the headend is the configuration where in terms of data that's being passed through so that it can pass pass into the MDM. And that's why our MDM and headend are tightly integrated as one package.

Meter Data Management Systems

Meter data management systems, or (MDMS) are powerful data analytics software systems for use by utilities to interpret data from AMI systems. At a mid-sized utility like that in this study perhaps 25-30 people access the MDMS regularly. There is a significant range in capabilities in many of the MDMS on the market for utilities to choose from. If a utility wanted to get involved with programming and producing customized reporting from AMI data, the MDMS was important to them.

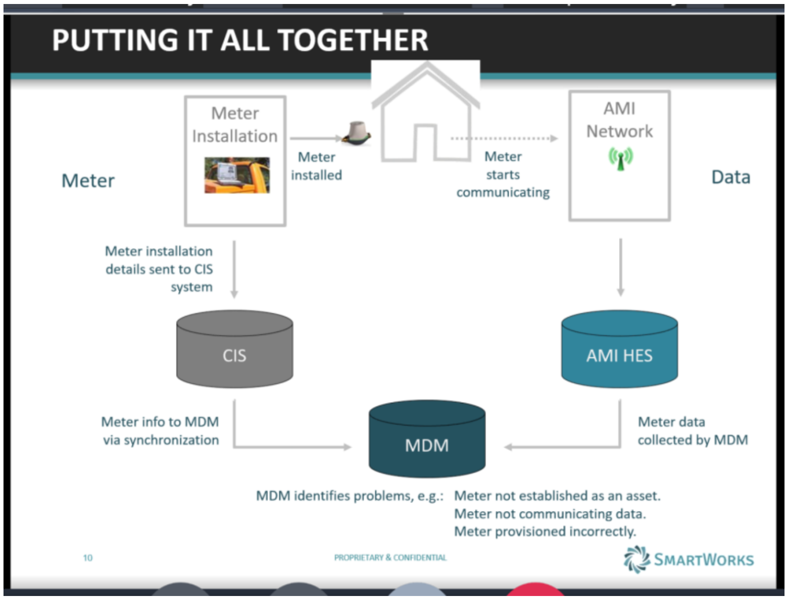

Figure A.11. Putting It All Together.

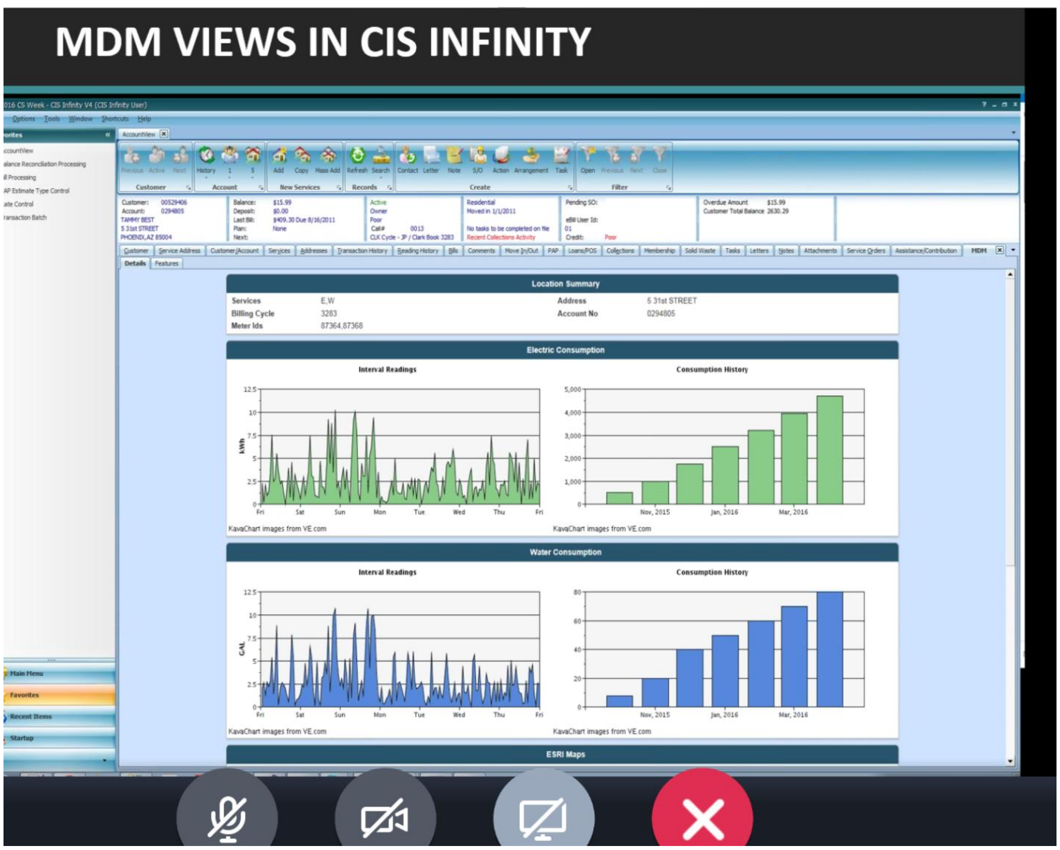

Figure A.12. MDM Views in CIS Infinity.

Figure A.13. MDM Reporting View

Customer Engagement Portals

The last component was the Customer Engagement portal (CEP). CEPs were the public facing software the water customers used to access and interact with their usage data and, if the CEP was linked to the billing software, also pay their bill. CEPs allowed customers to perform a range of actions, including setting monthly water budgets, set alarms for leaks, and get tips on how to save water. A figure of a typical CEP is below.

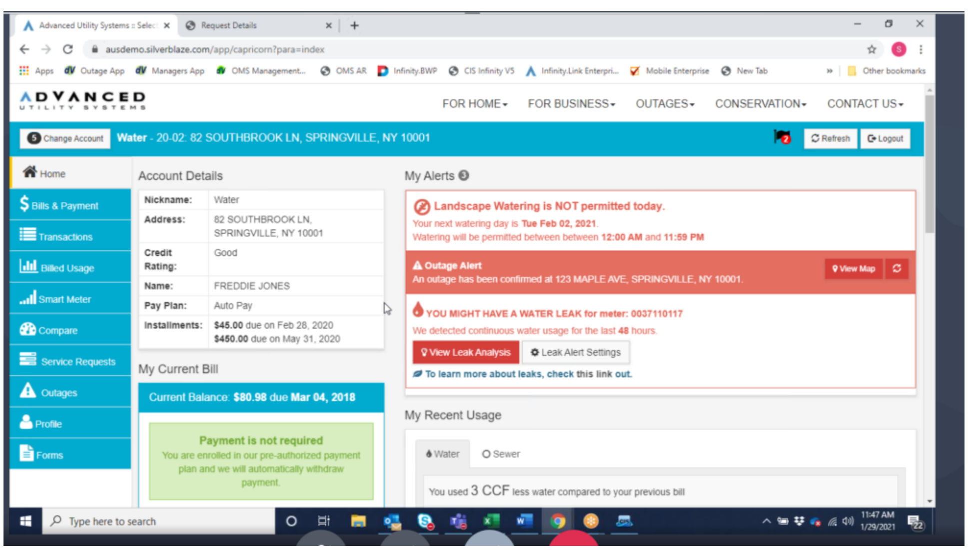

Figure A.14. Typical CEP.

Appendix II. Historical Background

Technological change in metering and the experience of digitization

With advancements in digital technologies, firms developed and introduced many new metering technologies for gas, electricity and water metering. Both Fogtown and Suntown were exposed to new possibilities for organizing metering work. Their approaches differed significantly. Fogtown's early, aggressive and haphazard approach to digitization produced a patchwork metering system of many different types and generations of metering technologies. The complexity of the system made meter reading difficult and prone to integration errors. Suntown, in contrast, had held back on adopting new digital technologies and maintained an almost uniform system of mechanical meters and registers that meter readers visually read by walking long routes. This meant that the organization of metering work at Fogtown looked very different from Suntown's. Work in Fogtown's meter shop was a hectic "firedrill" the first two weeks of every month as the crew tried to gather reads before the billing deadlines from five different types of systems, each with their own types of failures and idiosyncrasies. In contrast, Suntown's meter shop was a much more predictable and reliable sequence of activities month in and month out. Both cities learned from their experiences with digitization to make predictions about later possibilities for digital transformation

Prior to the introduction of digital metering, metering technologies had remained largely stable for most of the 20th century. Cities initially transitioned from free or fixed cost water delivery to metered service in the first decades of the 20th century. To bill for water use agencies installed mechanical meters and registers that indicated the volume of water that had flowed through the meter to the customer. Water departments used the information from the register to bill residents for their water use. Mechanical meters, also called "displacement meters", measure water as it flows through the meter to the customer's pipes. Meters have a disc inside a precision chamber that nutates (or wobbles) in response to volumetric pressure. Water physically displaces the disc in proportion to the amount of water that passes through the meter, and the precise cycles of the nutating disc revolve a magnet that turns the dials on meter's register by a tenth of a cubic foot or by gallon. In manual systems, which was in place at Suntown, meter readers walk many miles to visually read the mechanical dials and gather volumetric data, called "reads". Routes at both agencies are still called "books" because historically meter readers carried leatherbound books for each route and updated the volumetric consumption by hand. On the west coast, where warmer temperatures allowed for meter boxes to be installed in the sidewalks in front of homes and businesses, reading a meter requires a meter reader to crouch down, lift a heavy lid off the meter box, dig out any dirt packed in by gophers, scrape off the face of the register, and take a visual read of the dial on the register. Before digitization, meter readers delivered completed books to the finance staff who produced and sent out regular bills to water customers in the agency's service area. In recent decades the institution of utility metering, including water, electricity, and gas, experienced a significant influx of new digital metering technologies that change both the way water is measured and displayed at the meter, and how usage data can be collected by metering staff.

One area in which firms have developed new technologies has been methods of volumetric measurement. New technologies can measure water in different ways within the body of the meter. Instead of mechanical displacement meters, many agencies have installed velocity meters. Velocity meters measure water's volume by deducing it from its volumetric flow rate. The volume flow rate calculates how much matter moves through space per unit time, which is measured in a physical dimension such as volume, rather than mass. Volume flow rate can be used for liquids and gas, but not for solids as they do physically flow in the same way that gases or liquids do. For example, when a water customer runs a garden hose, a given number of gallons of water passes out of the end of the hose in a given amount of time (usually seconds or minutes). This amount is considered the volume flow rate. There are two ways to determine velocity: the Doppler effect, or "transit time". Both methods rely on the use of ultrasonic waves within the water meter.

Other technologies altered the way in which volumetric reads could be gathered. The biggest shift was the introduction of large, digital "handhelds" that meter readers carried and punched in reads as they walked the routes. Instead of delivering handwritten volumetric notes, meter readers could transfer digital files to computers used by the finance office for billing. Some agencies installed digital registers that converted the analog signal to digital register face. Other agencies installed “touch” systems where meter readers could carry slender wands that captured reads digitally when they touched the tip of the wand to a transponder on the outside of the meter box. Touch systems relieved readers of the taxing physical labor of opening up hundreds of concrete boxes a day. New systems called “automated meter reading”, or AMR, used radio transponders on each meter to ping volumetric data over short distances. Instead of walking, meter readers could drive routes in trucks equipped with data collector units. AMR represented the possibility of cutting the time it took to read a route to a fraction of the time.

By the 1990’s, new technologies were widespread and both workers and managers in meters shops could see and hear about other ways of metering their service areas from neighboring agencies, consultants, and industry events. Whenever metering staff heard about new metering technologies, they could begin to imagine how it might impact their own agencies, and their own work. Meter shops did or did not transition to new technologies for different reasons, and any changes evolved on timelines that were unique to each agency. During the first period of digitization, Fogtown and Suntown took different approaches to technological change.

From analog to digital at Fogtown. In the late 1990’s at Fogtown the meter shop was a small five-person group responsible for managing the meter system and capturing volumetric reads in a bi-monthly basis. The shop was located on the other side of town from the rest of the department and had a reputation for doing things their own way without involving or bothering the other sections. In the 1990’s, Mick, the meter shop supervisor, began hearing about a new technology called automatic meter reading (AMR). Mick learned about AMR from a neighboring county and took it upon himself to understand how the technology might improve metering work in his group. He was interested because he wanted to improve both customer billing and metering work. First, he felt that the customers would be better served by a monthly bill instead of an expensive, bi-monthly charge:

> When I started here we read meters on a bi-monthly basis. We were going around reading them visually. And then I'm the one that kind of got the ball rolling with the AMR replacement here back in 99. We wanted to get the customers on a monthly bill as opposed to a bi-monthly bill and ease the shock of opening up a big bill every 60 days…. And I thought the benefit of just being able to jump in a car and go around and spend 15-20 minutes on a route as opposed to two or three hours was pretty obvious.

Mick predicted that the new technology could cut the time it took to read a route dramatically, enabling more frequent billing. AMR systems require meters to have a sensor that converts the analog signal from the register to a digital number indicated the current read. Small radio transponders affixed to the meter "ping" the data to a nearby radio receiver. Transmitters, or "MXUs", have batteries in them which are designed to last many years, as they only ping for a radio signal a few times every hour. AMR systems are also called "drive by" systems because meter readers usually drive routes to capture the reads without leaving the truck. Mick was enthused at the prospect of reducing a route read time from several hours to just twenty minutes. This time savings would help customers, but Mick also predicted that it could help him solve other problems in the meters shop.

Mick was struggling with metering staff who were shirking work. Instead of walking routes and reading meters, Mick suspected that many of his staff were making up, or "curbing" reads and taking the rest of the day off. If this were true, then the data that the water agency used to bill for usage and fund the entire department could be incorrect. Hunter, a utility account specialist at Fogtown, explained why Mick was keen to adopt an AMR system:

> The city went to AMR because the meter readers were curbing reads. They would make up reads for every meter. Mick even hired a private investigator to trail them and he caught them on shopping sprees in the middle of the workday. So then they eliminated nefarious human activity. All those guys got fired.

Hunter understood Mick's motivation to pursue the technology as part of the prediction that it would eliminate the opportunity for "nefarious" human activity. A number scribbled in a route book was easier to falsify than a data file received from an AMR system. Falsifying meter reads was bad for the customers and the department's reputation, but in Mick's mind, falsifying timecards was an even more serious infraction:

> They were fudging their timecard as much as they were fudging the reads. We had a lot of bad reads coming in and they weren't finishing their routes. So I hired a private investigator to watch them to see what was going on. I mean, it got to be that bad. We found out one of them spent two hours out shopping and then would go back and do a few reads and then go home and have lunch. They just weren't doing their job. So yeah, they got fired for lying on their timecards.

Mick needed to clean up his meter shop and prevent any future infractions. With most of his meter readers fired and a new crew hired up, in 1996 Mick moved quickly to acquire an AMR system. AMR technology at the time was first generation and not widely used, so he ran a pilot with one of the major firms producing AMR transmitters. The firm upgraded a few hundred meters and Mick's staff tested on the new drive by method. The pilot did not go as well as he had hoped, however:

> The first generation MXUs [transmitters] kind of failed miserably. It all worked great when they were installed, but after the first rains they had a problem with the spotting on the MXUs that caused the moisture to get into the boards and zap themselves. So it was one of those things where took a step back… I convinced the customer service manager we could do this in house for much cheaper than it would cost to have a contractor to come in and do it. And the rest was history, they we got the money and, and the project got started. We installed meters in house for eight and a half years. Now, all that being said, I probably wouldn't do it the same way again, just because especially with AMI, you would, you'd never recognize the benefits of it, waiting eight years to get it all installed.

Mick had a reputation of keeping his head down and getting things done without bothering other in the department. The pilot had gone badly, but he believed that the firm would make good and fix the problems during a full roll out. After talking through his frustrations with the outside firm, he proposed to convert the city's entire meter system over to AMR without hiring an outside contractor. Given the green light, Mick organized his own staff during the week and during weekend overtime hours to replace the City's entire system of over 20,000 meters. Everyone worked long hours to move the project forward, but Mick ran into problems almost as soon as he got started, as MXUs began to fail before he was finished installing, and his staff were quickly overwhelmed by trying to fix the recently installed transmitters, installing new ones, *and* capturing customer data within the required billing cycle. The AMR troubles meant that the City never got to recognize the benefits of the new technology. As the Evan, the customer service supervisor explained:

> For us, the project was like painting the Golden Gate Bridge. You start on one side, and by the time you get to the other you have to start all over again from the beginning. You never got to step back and enjoy a freshly painted bridge. The meters began having issues a few years into the program, so the maintenance work really started to catch up and even take over the install work.

The effects of the failures spread, and many began to assess that the promised benefits of both easing the work for the meter readers and achieving a monthly bill for customers turned out much differently than they had predicted. The new technologies had produced more problems than they had started out with. Evan summarized the project in a memo to the department in 2016:

> In retrospect, what looked like a momentary hiccup in the winter of 1996 was really a foreshadowing of the Achilles heel of automatic meter reading: automation. Before radio, meter reading "technology" consisted of a hook, a book, and a comfortable pair of boots—all sturdy pieces of equipment requiring little to no maintenance. With the advent of radio, meter reading technology mushroomed into many, many moving parts, all requiring power and each a different but interlocking point of potential

> failure: hook, book, and boots were replaced by encoder wire, battery, and circuitry. To be sure, AMR saved the time it once took to read meters manually, and it saved the backs, shoulders, wrists and knees of the men and women who performed this task. But the promise of devoting the time saved with AMR to the oft-deferred tasks of meter testing or route maintenance never materialized.

Evan's memo describes the many ways in which the AMR transition was troubling for not just the meter shop, but anyone in the meter-to-cash workflow. Over the decade during and after Mick's installation program, the rest of the department started to experience a variety of negative side effects of poor data, missing reads, and missed billing deadlines. Jeannine, a Customer Service Representative (CSR) in the billing department, explained her experience with the change in this way:

> When I started [in the late 1990's] we had just changed to radio [AMR] reads, which was… interesting. There was a learning curve there, and a whole different set of things that went wrong. The meters would wake up in the middle of the night and talk to each other and drain their batteries, you know, weird things. It's like that when you switch to something new and you are learning how to use it as you're putting more in. We have 30,000 accounts and it took a while, so that was a huge change. Every single time we switch to a new technology it creates more work, more complicated work. It rarely makes anything easier.

For Jeannine, the AMR failures contributed to her prediction that any new technology would make her job more difficult. Her experience with failed meter contributed to her sense that her job would become more difficult with new technologies. Effects of the transition echoed for decades throughout the Public Works Department, and anecdotes from the period came up in the form of predictions for the AMI system.

Mick attempted to fix the system on the fly, but this produced more problems than it solved. When he saw a possible solution, he tried to implement it immediately. He was beset with problems with the AMR transmitters and he wanted to put things right. Rather than stepping back and making a longer term game plan, Mick cycled through different technological fixes one after another. When new generations of transmitters came out, he started to buy those. When he had the option to use transmitters on a cellular network instead of a radio network, he tried those out. For many years he could trade out the prematurely dying batteries in the first generation transmitters, but later generations didn't allow for battery swap out and he was forced to buy whatever new transmitters were available. Mick's DIY approach to repair transitioned the City of Fogtown from a fully mechanical, manual system to a complex hybrid system of different digital technologies that was often referred to as a "mixed bag", "mess", or at least "a bad idea". By 2016, he had updated a few hundred meters with new AMI transmitters on a pilot to see if the new system could solve their problems.

By the time Fogtown was learning about and making predictions for an AMI system in 2016, they were beset with problems related to the hybrid technologies in place. Once the AMR system was fully installed, Fogtown split the month up into two parts. In the first half of the month the meter shop gathered reads before the billing deadlines, and in the second half of the month they repaired meters. This gave the billing staff time to process the final meter data and get bills out during the second half of the month. Over time, the system had become strained and he was unable to either capture high quality reads or catch up on repairs before the next month started. Each metering technology had its own method of capture and associated problems. As Evan explained:

> AMR not only added a whole new layer of maintenance to meter reading (which consequently negated the efficiencies of the technology), but it also paved the way for the transition from bi-monthly to monthly billing, effectively *shortening* the time available for personnel to address MXU failures.

The meter shop took to calling the first half of the month a “firedrill”, during which they did drive-bys for the AMR meters, walked one route installed with touch transmitters, manually checked a few mechanical meters, and then did repeated “go-backs” to all of the meters that had failed to transmit a reading. Mick explained:

> Well, I mean, the fire drill thing is something that we’re just we were used to now. But it’s just not efficient at all, by any means. It’s a way of getting reads every month, but it’s kind of just a scramble mode from the first of the month to the 15th of the month. And that’s when we’re typically done with our reading schedule, but every month, there’s more and more meters that we have to physically go to to actually get a read.

Fogtown’s experience with first generation digital change at the meter shop was disappointing for everyone involved and had produced a difficult set of initial conditions from which to make the move to an AMI system. Relationships between the meter shop and the rest of customer service were strained. The billing staff and the meter shop were physically separated by several miles, and neither knew much of what the other was doing every day. Billing staff no longer felt confident that the read they were giving customers over the phone was correct, as one customer service representative explained:

> When I started 20 years ago it was all mechanical meters and the one thing that was drilled into my head was meters don’t lie. People can misread them but meters tell the truth because they are mechanical. When they break they slow down, not speed up. With AMR all of that went out the window. We were getting weird numbers. It was mostly based on the fact that the way the meters were programmed. The vendor added or subtracted the number of digits that would show up on the read- so I would be off by an order of between 10 and 1000 and we would have these huge reads because it wasn’t coming in correctly... It’s just like ughhh. I don’t trust it. Because I know all of the ways it can go wrong.

From the billing staff’s perspective, problems were a combination of the buggy technology and the fact that the meter shop was not doing their job. They sent over unverified and impossible reads to the billing staff, as if houses had used an order of magnitude more water one month to the next. They increasingly sent over either poor data, or reports with a lot of missing reads. The billing supervisor was forced to send out her own field techs to check on suspect or missing reads in order to meet her own deadlines to get bills out the door. In the following example, Julia, the billing supervisor, meets with Evan, the customer service supervisor, to figure out why the data from the meter shop was so bad:

> Julia- What I want to find out.. I don't know what happens over there [in the meter shop]. I think Mick's not fully capitalizing on his staff or how he uses them.
>
> Evan- So they didn't upload the data. I think there's increasing failure, lots of go back readings, and introducing human error.
>
> Julia- I don't know what it takes to do to that, but my staff can do 150 tags [meters] in a day, so 30-40 doesn't sound like a lot to me. Why can't he get to the missing reads on his own?
>
> Evan- I agree. 30-40 should be do-able.
>
> Julia- There is a disconnect between numbers and work getting done for me. I mean, I have no idea. I'm not over there. All I know is that it's affecting us over here.

The state of the metering system put Evan in a difficult position. He had to manage both the billing staff and the metering staff, and he was sympathetic to both groups. He had worked in the meter shop early in his career, and he knew how difficult it was to capture, validate, and send off accurate meter data in such a hybrid system.

Past failures with capital improvement projects at Fogtown. A second project in which Fogtown's water department staff gathered information to make predictions about AMI was through their experiences with and around other capital improvement projects (CIPs), such as the building of treatment plants or accessing new supply sources. Workers who had participated in earlier capital improvement projects developed a sense of how change occurred in their organizations. Those who were not directly involved heard stories from coworkers and supervisors about past projects.

At the time of this study, Fogtown agency workers had recently gone through a CIP that a superintendent described as both "traumatic" and "demoralizing". The Water Department had undertaken a major desalination plant initiative in partnership with a neighboring water agency, only to have the city council quash the project in the last public meeting before final approval. Murial, an analyst in the department described the project:

> I'm not joking, we spent 10 or 15 years working on this desalination project and $15-20 million went into building a pilot. We were all ready to go and we kept going to City Council and they kept approving it every step of the way. Then we took it to Council one last time and they rejected the whole thing! It has hurt the water department so much because we're talking about a decade's worth of work that people put into this project. It was a solution to our water supply problems!

Several staff who had spent so much of their career building a pilot program for the project brought up the impact on departmental morale repeatedly over the course of this study. A key frustrations that agency workers often mentioned was that City Council could be swayed by a small group of fringe activists despite the department's taking great care to mitigate any potential negative effects of a new supply project like desalination.

The small group of staff who wanted to mobilize the city around a digital transformation project had a lot of obstacles ahead. Experiences in the city with the AMR decades, combined with the blow to morale during the desalination effort, meant that most employees had pessimistic views about an expensive, complicated technology project.

Proceeding with caution: Digitization at Suntown

Compared to Fogtown, Suntown's experience with digitization had fewer instances of technological change. The most salient difference between life at the two meter shops was that Suntown's meter shop was not hampered by the same or nearly as many problems as Fogtown's. In contrast to Fogtown's temporal division between metering and billing, Suntown organized the meter-to-cash workflow on continuous cycles. Meter readers read throughout the month and turned in reads in advance of a given billing cycle's due date. The billing staff worked on bills throughout the month rather than starting and stopping over the billing period. This meant that Suntown reliably sent out bills to customers on a monthly basis without the pressure of capturing every read in a two-week window. This balance had come from a correction to a poorly managed workflow in the past.

An earlier meter shop supervisor pushed meter readers to read several routes a day, but the meter readers physically suffered under the grueling schedule and the supervisor was fired and replaced with Peggy, who let the meter readers organize their own schedule as long as they got the reads in on time. As Javier, a long-time meter reader, now working as the lead for the group, explained:

> It's not too hard to keep on schedule. I've been doing this for many years. Before it was really hard. Our old supervisor had some wrong ideas about the number of accounts we should do per day. We read all day every day. We had to read every day even if somebody's sick, is on vacation, we still have to read their routes. So yeah, he made things hard. Once Peggy took over the supervisor, she was, "You know what? You do the schedule however you want. [laughter]." So now I kind of clear everything and make the schedule that works better for us.

One change Javier made immediately was to balance out the difficult routes among the group. He had felt that the older supervisor punished meter readers he had not liked with the most difficult routes. Javier made the group a promise that he would give them a few days heads up on the routes they would do as long as they promised not to call out sick on the difficult days. That way they could bring whatever they needed to get through the longer or more difficult hilly routes and share the burden. Javier himself suffered from injuries he sustained during the more grueling schedule under his old supervisor. He had several surgeries on his arm for carpal tunnel syndrome and was in the middle of negotiating with his insurance to get another surgery. In general, Javier described the group as working well together and getting things done with a good attitude.

Peggy wanted to try out a digital AMR system, so she contacted the firm from which they had sourced their handheld devices for walking routes to set up a small pilot of AMR transmitters on their more dangerous and hard-to-reach meters. Her group's experience with the AMR meters was mostly positive, but their interactions with the firm and in trying to fix problems that came up with the technology bolstered their impressions that technology firms promised a lot more than they could deliver. Arnoldo, a long-time meter reader, explained the slow start on trying out AMR:

> What I liked about [AMR] was having it in areas with limited accessibility, or in places that were dangerous, it seemed like it was gonna be helpful. But the early start was rough. My lead tried to get it figured out in every which way, every combination to see what would work, and until Peggy finally came on, we finally got it figured out. But you know we really didn't use it much when it first got here, a lot of the stuff just sat in the storeroom. When Peggy finally got a hold of the company, we finally got a handle on it.

Arnoldo liked the idea of doing drive-by reads for hard-to-reach meters and high traffic areas, but he also saw how hard it was to get things off the ground. Peggy explained that she was repeatedly held back by poor communication and slow action on behalf of the firm that produced the AMR transmitters:

> I definitely am a little irritated with [the AMR company]. I'm trying to keep things from unraveling as we're moving forward. Things could have been up and running and going a lot sooner if they had sent us the equipment we needed. I mean we created the PO [purchase order] to purchase the DCU [data collector unit] and they didn't actaully deliver it to us until many months later. They were like "ohhh we've got a lot of other orders" and I'm like, "you can't set aside 1? you can't set aside 1 for our pilot?" And then I really had to put my foot down when they said "oh it's so easy, you can just do this, you can set this up yourself."
>
> I had to put my foot down and say no, this is taking way too much time, and you need to come here and make this work if you want us to pilot with you. Since then just a simple software installation with the AMR pilot was a hassle. I opened the help desk

> ticket in mid may and it wasn't installed until the end of June- that could really.. if a lot of things hinge on that.. it's a month and a half before that process happens that pushes everything else out a month and a half. We can't have that if we need to read within the billing cycle.

Unlike Fogtown's decision to overlook failures during the pilot program, Peggy took the disappointments to heart and remained skeptical about the reliability and value of new digital technologies. By 2016, the only digital technologies the Suntown meter shop had adopted for use in the field at scale were the digital handheld devices that meter readers carried to punch in the volumetric reads on their routes.

Suntown had many opportunities to transition to new digital metering technologies in the twenty years leading up to the beginning of planning for a transition to AMI. In reflecting on their experiences in the decades leading up to the beginning of their AMI transition, Suntown's supervisors emphasize two qualities of their approach to new technologies. First, their general impression of new metering technologies was that firms tended to overpromise and underdeliver, and second, supervisors were careful to consider the long term maintenance needs of any new technology. They learned about and tried out new metering technologies in small, low-impact test cases, including ultrasonic meters, meters with pressure or temperature sensors, or remote shutoff capabilities, with a degree of skepticism. Peggy, the meter shop supervisor, explained her experiences with new metering technologies in the recent past:

> We've tried several different metering technologies for just the meters themselves over the last 10 years. Some of them have been OK and others have really not shown the success that we would want, like failing within five years of installation, not really having all of the features, not being as maintenance free as you know advertised.

Peggy was interested in the new meters enough keep tabs on changes in the industry, but her comparison was always to the long term reliability of the mechanical meters on which they had depended for almost a century. Her staff shared her “wait and see” approach to new technologies. Cameron, an hourly meter reader, described

> The technology is just starting to kind of get to the point where it’s kind of feasible. I say that because the technology is there, but it’s still not all the way there yet. These things actually require a lot of maintenance and a lot of people’s time to trouble shoot them, maintain them, and deal with them.

Suntown’s approach meant that when their transition to AMI was a greater leap than that at Fogtown. Whereas Fogtown had already shifted from a manual to a digital meter system, Suntown’s meter readers still walked 5 to 10 miles a day visually inspecting each and every meter in the City.