Dynamic Capabilities for Water System Transitions in Oklahoma

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Abstract

Based on semi-structured interviews with key decision-makers from 38 distinct municipal water utilities in Oklahoma, this paper examines the innovation process that drives water system transitions in response to external pressures, including climate change, policy, and economic trends; and to address internal system needs, such as supply expansion and infrastructure upgrades. A multiple linear regression analysis reveals a strong, positive relationship between innovations and dynamic capabilities, suggesting that dynamic capabilities are crucial to the transition of water systems. The strength of the relationship between sensing, seizing and reconfiguring dynamic capabilities and innovations differs by type of innovation. Water manager awareness of the state-level Water for 2060 Act was shown to have significant influence on the number of innovations generated by municipal water systems, while water manager licensure level was not a reliable predictor of innovation. Recommendations for encouraging much needed radical innovations are outlined.

Keywords: dynamic capabilities, public water utilities, sustainability transitions, incremental and radical innovation, Water for 2060 Act, Oklahoma

1.0 Introduction

The continued safe operation of water systems is threatened by the slow pace of institutional and infrastructure change, which characterizes not only rural but also urban regions in the United States. Funding pressures, especially budget cuts, have limited the ability of water managers to instigate incremental—let alone radical—changes that would improve the sustainability of water systems. This empirical study examines the innovation process in 38 municipal water systems in Oklahoma. Innovation is defined broadly as the creation and implementation of new or adapted institutional and technological changes that generate value and enhance water system sustainability. The antiquated state of the water system infrastructure in the United States and Oklahoma (American Society of Civil Engineers, 2013), combined with a changing climate (Karl, et al., 2009) and increasing consumer demand for water (OWRB, 2015a), provides a window of opportunity for studying innovation in public water systems (Hering et al., 2013; Pahl-Wostl, 2007; Spiller et al., 2015). Addressing the innovation deficit in water systems (Kiparsky et al., 2013) requires understanding how changes to institutions and infrastructures can be encouraged at multiple levels. A key question is how best to initiate and facilitate innovation processes, which lead to water system changes as part of transitions towards sustainability (Lieberherr and Truffer, 2015).

A recent theme in water governance involves the integration of strategic decision-making theory and methods to help understand how the water sector can implement more sustainable infrastructure (Ashley et al., 2008; Lienert et al., 2015; Scholten et al., 2015). This is particularly true when examining how dynamic capabilities--"the ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece et al., 1997,

p. 516)--can help water managers in creating value with innovation (Lieberherr and Truffer, 2015). The key feature of dynamic capabilities is that they allow organizations to quickly modify resources or routines in response to opportunities or threats (Zahra et al., 2006). Viewing organizations through a dynamic capabilities lens allows researchers to gain insight into the beginning stages of managerial actions that shape the organization and the innovation process (Lin et al., 2016; Narayanan et al., 2009). Research and development, product development routines, organizational structures, strategic decision-making, human and social capital, and external alliances are examples of dynamic capabilities that are adaptable and have the potential to lead to innovations (Eisenhardt and Martin, 2000).

While incremental and radical innovations are both crucial to the success of utilities, radical innovations increase the long-term viability and capacity of the water system (Kiparsky et al., 2013; Gaziulusoy, 2015). Incremental innovations are more frequently implemented in municipal water systems to ensure system stability (Thenint, 2010), as urban water management is generally averse to risk (Lemos, 2008; Thenint, 2010; Bekkers et al., 2013; Hering et al., 2013). When an innovation involves a drastic change, similar to the application of wastewater reuse, it is considered radical because it requires combinations of specialized ideas, knowledge, expertise, and social acceptance (Damanpour and Schneider, 2009; Gaziulusoy, 2015). Radical innovations in water systems include technologies that change how water is used (e.g. water reuse), measured and billed (e.g. smart meters), as well as management and business models based on strategic planning and adaptive learning mechanisms (Kiparsky et al., 2013).

1.1 Research Question

The creation and deployment of sensing, seizing and reconfiguring dynamic capabilities were studied to understand the process of innovation in Oklahoma’s water utilities. Given the importance of dynamic capabilities to innovation (Eisenhardt and Martin, 2000; Lieberherr and Truffer, 2015; Michailova and Zhan, 2015; Weerawardena et al., 2015; Forés and Camisón, 2016; Lin et al., 2016), the identification of green dynamic capabilities (Lepoutre, 2008; Gliedt and Parker, 2010), and the verification of sustainability-oriented sensing, seizing and reconfiguring dynamic capabilities for green technology, knowledge generation, and innovation (Chen et al., 2015), we seek to examine a relationship between *the level and type of dynamic capabilities and the level and type of water system innovations in water utilities.* Various factors are used as controls including average household income, the population size served by the water utility, the licensure level of the water manager for each utility, and awareness of the Water for 2060 Act by the water manager.

Dynamic capabilities offer an empirically testable explanation of change in the water sector because they have been shown to contribute to innovation (Lieberherr and Truffer, 2015). The Oklahoma case study, which is described in the methods section, is particularly useful for studying dynamic capabilities development and use given the historically low rate of innovation that characterizes the water sector (Widener et al., 2016). The remainder of the paper reviews the literature on dynamic capabilities, describes the research question and the methods used to examine it, outlines the results, and concludes with the key findings and recommendations.

2.0 Literature Review

2.1 Contested Dimensions of Dynamic Capabilities

Researchers continue to debate various issues that relate to the understanding of dynamic capabilities as part of innovation processes (Teece and Pisano, 1994; Eisenhardt and Martin, 2000; Lawson and Sampson, 2001; Zollo and Winter, 2002; Winter, 2003; Zahra et al., 2006; Teece, 2007; Lepoutre, 2008; Helfat and Peteraf, 2009; 2011; Lieberherr and Truffer, 2015). First, the level at which capabilities are considered dynamic is not always clear, ranging from routines and tacit knowledge, to the underlying capabilities that alter those routines in organizations (Winter, 2003; Helfat and Winter, 2011). Even those underlying capabilities must be created by some combination of resources and capabilities (Eisenhardt and Martin, 2000; Zahra et al., 2006). Dynamic capabilities are essentially the capability to create capabilities (Winter, 2003; Zahra et al., 2006), which in turn help solve problems or foster innovations. Zahra et al. (2006) propose that the effect of dynamic capabilities on performance (in this study performance is considered to be the number and type of innovations created) is related to higher levels of organizational knowledge.

Second, authors have critiqued the focus on structures and routines at the expense of the role of individuals in the innovation process, and in particular, individuals as the micro-foundations of dynamic capabilities (Felin and Foss, 2005; Foss and Lindenberg, 2013). A hybrid view is that a combination of individual leadership and routines/structures create, enable and activate dynamic capabilities (Foss et al., 2012). Structures, including environmental departments, committees, management systems, and formal strategic partnerships, can act as internal or external capabilities and can be used by champions to foster innovations (Gliedt and Parker, 2010; Lepoutre, 2008). Given the uncertainty in the literature, Devinney (2013) calls for research to examine the connections between the individual, and the structural and strategic elements of organizational value creation.

Third, some authors suggest that to be considered dynamic capabilities, they should lead to competitive advantage or financial benefits (Teece, 2007). Others argue that dynamic capabilities are a necessary but insufficient factor in the creation of competitive advantage, and are thus valuable in their own right whether or not outcomes are derived from their existence or use (Zahra et al., 2006). This debate is based on the assumption that positive outcomes (e.g. financial performance, competitive advantage) signify the existence and successful use of dynamic capabilities (Eisenhardt and Martin, 2000). Zahra et al. (2006) question this assertion, and suggest instead that the important outcome of dynamic capabilities is 'the ability to reconfigure as desired', rather than financial performance.

Fourth, the importance of leadership is evident in Zahra et al.'s (2006) conception of dynamic capabilities, which were defined as "the abilities to reconfigure a firm's resources and routines in the manner envisioned and deemed appropriate by its principal decision-maker(s)" (p. 918). Arend (2015) argues that organizations attain a competitive advantage by leveraging existing resources and capabilities, rather than acquiring and accumulating new resources and capabilities. The process of leveraging existing capabilities relies on leadership for setting the strategic direction for innovation.

Fifth, the degree to which the external environment is dynamic may influence the development and use of dynamic capabilities. Zahra et al. (2006) argue that dynamic capabilities exist in firms operating in both dynamic and stable environments, but that the use and usefulness of dynamic capabilities may be greater in organizations operating in dynamic environments. In the case of public water utilities, dynamic environments include those with population or economic pressures, or those experiencing climate changes in the natural environment such as measured precipitation changes and its perceived impact on the water system.

2.2 Sensing, Seizing and Reconfiguring Dynamic Capabilities in Water Utilities

Teece (2007) identified three main types of dynamic capabilities as sensing, seizing and reconfiguring, which have been shown to be important to innovation in water systems (Lieberherr and Truffer, 2015). These types of dynamic capabilities can help water utilities demonstrate and draw upon internal and external knowledge, learning and adaptation as part of the innovation process (Lieberherr and Truffer, 2015). Teece (2007) argued that management must have the "ability to sense and then seize opportunities, navigate threats, and recombine and reconfigure specialized and co-specialized assets to meet changing customer's needs, and to sustain and amplify evolutionary fitness" (p. 1344).

Sensing capabilities can be used to discover the current focus and future directions of an industry by addressing potential opportunities and threats (Eisenhardt and Martin, 2000; Teece, 2007). Sensing capabilities include research and development, addressing consumer needs, determining the limits and capabilities of new technologies, and utilizing external organizations. Upon discovering an opportunity or threat, the organization must then seize the opportunity (e.g. mobilize resources to implement a change) and reconfigure the capability as necessary (e.g. modify over time in response to external changes). Sensing and seizing capabilities have a low and medium impact on how the water utility is run, while reconfiguring a high impact because it involves restructuring the organization itself (Lieberherr and Truffer, 2015).

Lieberherr and Truffer (2015) found that sensing activities in water systems may develop from external interactions with industry competitors, government regulators, authoritative institutions and universities, as well as the knowledge and educational backgrounds of decision-makers. External interactions often take the form of mergers and acquisitions, joint ventures, strategic alliances, or personal relationships (Teece, 2007; Lieberherr and Truffer, 2015). Sensing capabilities are critical for matching internal or collaborative solutions with external problems. Sensing capabilities are those that:

relate to the strategic identification of future development paths in the sector through such means as R&D. Besides formal in-house capacities for detecting and creating opportunities, utilities may draw on competencies in their broader environment by engaging in regular collaboration and exchange with experts in research institutes, universities or professional associations (Lieberherr and Truffer, 2015, p. 109).

Seizing capabilities require timely execution by senior management who share a united vision (Teece and Pisano, 1994). Lieberherr and Truffer (2015) found that water utilities implemented various innovations based on seizing capabilities, including solar technologies, drought plans, new water treatment processes, and smart meters. Seizing capabilities are defined as the process of:

translating future options into promising product and process innovations within the utilities by implementing and investing in new technologies or adopting alternative approaches. Of particular interest here is the relative importance of incremental innovations in comparison with substantially new technologies and business models (Lieberherr and Truffer, 2015, p. 111).

Organizations must also be able to reconfigure their capabilities by re-evaluating the allocation of resources to projects with greater potential success (O'Reilly and Tushman, 2008). New styles of treatment plants, new business models, and strategic planning were all identified as reconfiguring capabilities in water systems (Lieberherr and Truffer, 2015). Reconfiguring dynamic capabilities refer to:

the willingness and ability to actively contribute to alternative trajectories, to become a leader in the innovation field, where long-term strategic planning and a willingness to take risks play key roles. This relates to internal innovation and knowledge management of a water utility by devolving decision-making so that management has increased discretion over new technologies and knowledge integration within the organization (Lieberherr and Truffer, 2015, p. 113).

2.3 Relationships between Dynamic Capability Type and Innovation Type

Recent studies offer empirical support for the importance of dynamic capabilities to innovation processes (Eisenhardt and Martin, 2000; Chen et al., 2015; Michailova and Zhan, 2015;

Weerawardena et al., 2015; Forés and Camisón, 2016; Lin et al., 2016). Chen et al. (2015) found that external knowledge absorptive capacity had a positive influence on the creation of green dynamic capabilities, which in turn influenced green innovation and firm performance in Taiwanese electronics firms. Forés and Camisón (2016), on the other hand, considered internal knowledge creation and external knowledge absorption capabilities to be dynamic capabilities themselves, which positively influenced innovations within Spanish non-energy industrial firms. Internal knowledge creation capabilities were more related to incremental innovations, while external knowledge absorption capabilities were more critical to radical innovations (Forés and Camisón, 2016).

It is therefore anticipated that the type of dynamic capabilities will have different effects on the type of innovations created and implemented by the water utilities. Sensing, seizing and reconfiguring dynamic capabilities have been found to have varying impacts on organizational operations (e.g. ranging from low to high impact), and are important at different stages of the innovation process (e.g. from searching for new ideas, to implementing those ideas into innovations, to transforming the organization itself) (Lieberherr and Truffer, 2015; Teece, 2007). Innovations may be created with the help of internal or external processes, which would require different types of dynamic capabilities (Lepoutre, 2008). For instance, innovations that are institutional in nature may require different types of capabilities (e.g. social and relationship capabilities) than those that are infrastructure focused (e.g. capabilities for leveraging financial resources). Radical innovations may also need different types of dynamic capabilities that are more effective at supporting difficult, expensive, large scale and pervasive structural changes (e.g. reconfiguring dynamic capabilities), in comparison to the types of dynamic capabilities needed to make easier, less costly, smaller scale and incremental innovations (e.g. seizing dynamic capabilities).

3.0 Methods

3.1 The Oklahoma Case Study for Water Innovation

Oklahoma offers an intriguing case for examining water system innovation because of the creation of a statewide water policy, which was featured as a national example for water management and innovation at the White House Water Summit (OWRB, 2016). In 2012, the Oklahoma legislature passed House Bill 3055, more commonly referred to as the Water for 2060 Act. To accomplish the goals outlined in Water for 2060, Oklahoma's towns and cities must transition their water utilities to mitigate risks that threaten the availability of water resources for current and future generations. Significant changes are needed if Oklahoma is to meet its target of using no more fresh water in 2060 as it did in 2012 (OWRB, 2014a). This equates to a 33 percent reduction in water use by 2060, something that will be even more challenging given that every region of Oklahoma is projected to see an increase in demand for water in the business-as-usual scenario (OWRB, 2012b).

Water for 2060 is an important piece of legislation for two reasons. First, it may help to coordinate water management plans and actions across the state. This is critical given the drastic geographic differences within Oklahoma with respect to income, population, quality of infrastructure, and precipitation patterns (Widener et al., 2016). For example, the variability of precipitation patterns is quite extreme, with the semi-arid panhandle and western regions of the state averaging only 20 inches of precipitation, while central and eastern Oklahoma receive 35 to 50 inches of precipitation annually (Figure 1). These disparities are further amplified by frequent droughts (OWRB, 2012a). In December 2014, drought conditions impacted nearly 1.5 million residents, as Oklahoma had its eighteenth driest year since 1921 (OWRB, 2014b). In 2015, extreme rainfall events brought many of these previously drought stricken regions their annual precipitation totals in less than two months. Oklahoma went from a dry period that stressed its water and economic resources to a statewide flooding event that tested the resilience of crumbling water system infrastructure.

Insert Figure 1 here.

Second, Water for 2060 provides an enabling policy for innovation that can help guide the transition of municipal water infrastructure. The Act promotes municipal education programs and incentives to develop various water system innovations, such as wastewater reuse and water conservation measures. Oklahoma's Governor Mary Fallin supported Water for 2060 in 2014 by implementing the Water for 2060 Drought Grant Program (OWRB, 2014c). By March 2015, public institutions had requested over $18 million for water conservation projects (Allen, 2015). Of these, $1.5 million were awarded for water efficiency improvements in four rural communities in the Panhandle and Northwest regions of Oklahoma (Boise City, Fort Supply, Shattuck, and Butler), which are expected to collectively save over 22 million gallons of water annually (OWRB, 2015b). This is in addition to Oklahoma's Emergency Drought Commission and Relief Fund, which awarded $1.13 million to four municipal water utilities, three of which are in the Southwest region of the state (Altus, Tipton, Hollis) and the fourth in the Panhandle (Guymon) (OWRB, 2013). Oklahoma also has a Drinking Water State Revolving Fund, which provides loans to rural water districts for improving drinking water infrastructure (OWRB, 2015c). During the past 30 years, the Oklahoma Water Resources Board has approved more than $3 billion in loans and grants for water system upgrades in Oklahoma (OWRB, 2015c). Given the propensity of grant and loan programs, it is reasonable to expect that these financial mechanisms have been used to support water system innovation across the state, in spite of a recent finding that Oklahoma is one of the poorest performing states on water conservation (Hornberger et al., 2015).

3.2 Semi-Structured Interviews of Water Decision-Makers

To examine the water utility innovation process in Oklahoma, data from semi-structured in-person interviews with municipal water system decision-makers were collected and analyzed. Interview participants were identified through a publication created by the Oklahoma Municipal League, which listed top personnel for municipalities by department. A total of 130 municipalities and rural water districts were contacted by telephone, and 29 percent agreed to participate. This provided a sample of 38 independent water organizations drawn from the population of water utilities statewide. One respondent was interviewed from each utility between November 2014 and March 2015. Of the 38 interviewees, 36 percent identified their primary job as water superintendents; 34 percent as a water director, manager or supervisor; eight percent as leading a maintenance department; eight percent as a water operator; eight percent as the city/town manager; and six percent as a water engineer or technician.

Interviews provide an effective method for gaining insight into real world experiences, interpretations, knowledge, and processes of the research participant (Opdenakker, 2006; Cachia and Milward, 2012). Using a semi-structured format gives flexibility as the interviewer has an influential role in channeling follow-up questions to allow for more detailed information on specific issues (Leavy, 2014). Face-to-face interviews were utilized in order to observe social cues and non-verbal communication, capture quick responses to questions, and incorporate a small degree of standardization within multiple interviews (Cachia and Milward, 2012). Participants had upper management status within their utilities, giving them the “ability to exert influence” through "networks, social capital and strategic position within social structures" (Harvey, 2011, p. 433). In contrast to lower level employees, upper managers are likely to be knowledgeable of both past and current practices, have access to private information, and possess the ability to gather appropriate resources and influence others (Harvey, 2011; Mikecz, 2012), which are of key interest to understanding innovation processes.

The interview guide included 28 questions and numerous follow-up questions (Appendix A). Interviews lasted on average 75 minutes with some exceeding two and a half hours. Each interview was transcribed and coded, with transcriptions averaging 60 pages in length per interviewee. A digital recorder, with consent provided by participants, was used to reduce the amount of information loss and to provide for successful NVivo coding, which enhances comparative analysis between various respondents (Clifford, n.d.). NVivo uses thematic coding, which enables data and responses to be organized in a more efficient manner (Welsh, 2002). However, NVivo's 'auto-coding' feature was not used for this analysis because it has the tendency to cause inaccurate coding by taking terms and phrases out of context (Welsh, 2002). To avoid this issue, manual coding was deployed while using NVivo's organizational tools through the use of node hierarchies. Nodes represent recurring concepts/items discussed in the interviews, which were ultimately quantified.

3.3 Operationalization of Dynamic Capabilities and Innovation

Nodes were modeled after the interview guide (Appendix A) initially and modified based on participant responses. Key NVivo nodes were derived from coding responses from open ended questions in the survey (e.g. Q's 8, 9, 11, 14, 15, 19, 20). These questions were used to follow-up and seek more detail regarding responses to the ordinal scale questions related to infrastructure quality (Q's 4, 5, 10), vulnerabilities of the water system to various risks (Q 7), the processes of creating innovations (Q's 13, 16, 17, 23), barriers to innovation (Q 21), and the types of dynamic capabilities involved in those processes (Q 17).

Dynamic capabilities were also identified and described by the interviewees within open ended responses to numerous questions. Unique coding assignments were given to each category of identified dynamic capabilities to allow for comparisons to characteristics of the utilities and their operating environment. To identify dynamic capabilities consistently, Lieberherr and Truffer's (2015) definitions of sensing, seizing, and reconfiguring were applied to the coding of interviewee responses. Dynamic capabilities were categorized based on interviewee descriptions of how they were used in the creation of innovations.

Interview responses were also coded to compare incremental and radical innovations based on the following definitions (Damanpour and Schenider, 2009, p. 512):

> "*incremental* or exploitative innovations are only minor departures from the existing practices and are usually easier to develop and implement."
>
> *"radical* or exploratory innovations are major deviations from the organization's current programs and practices and often require recombination of more specialized and diverse ideas and information."

The goal was to separate innovations that were minor in impact, easy and quick to create and implement, and/or had been done before, from those that would require large scale changes to infrastructures, institutions, behaviors and cultures, and/or operating procedures. Infrastructure innovation refers to changes to the physical water system components (e.g. pipelines, water treatment facilities), while institutional innovations are changes to the supporting governance architecture (e.g. policies, programs, fee structures).

Although innovations have been shown to be enabled by dynamic capabilities, uncertainty exists as to the degree to which the type of dynamic capabilities used to create innovations are associated with organization size (e.g. population size served by water utility), resources available for innovation (e.g. average household income of the service area), and knowledge levels (e.g. the education and certification level of the key water managers), factors that are thought to be important to water sector innovation (Spiller et al., 2015). Multiple linear regression analyses were conducted in SPSS version 20 to investigate the relationship between the dependent variable (the number of innovations per utility) and the independent variable (the number of dynamic capabilities per utility). Multiple linear regression models were also run for subsets of innovations by type as dependent variables (radical, incremental, institutional, infrastructure) respectively, and by different corresponding subsets of dynamic capabilities by type as independent variables (sensing, seizing, reconfiguring). The multiple linear regression models controlled for population size and the average household income of the area served by each water utility, as well as for the education and certification level of the water manager as measured by the licensure level and whether or not they had knowledge of the Water for 2060 Act.

Limitations for this approach included the fact that only one researcher was responsible for data coding. Given that dynamic capabilities are difficult to identify within organizational processes and routines (Lawson and Sampson, 2001; Easterby-Smith et al., 2009), it is possible that some dynamic capabilities were unidentified. In the event that multiple researchers participated in coding, alternative capture rates of dynamic capabilities might occur. It is important to note that the water utilities in the study were representative of geographic region, population and income, and water source type, and taken together, provide water to more than 50 percent of residents in the state of Oklahoma.

4.0 Results

The sample of water utilities was organized by population size of the service area. Of the 38 water utilities in the study, 17 were serving towns with less than 5,000 people, 15 were small cities with population sizes ranging from 5,000 to 40,000, and six were populations of greater than 40,000 (Table 1). The average number of dynamic capabilities identified and innovations created per utility was higher for the large population category, which also had the highest average household income. The median licensure level of the water manager was also highest in the higher population category, where all managers had a level A license and were professional engineers. Having knowledge of the Water for 2060 Act also differed across the population categories, with all but one of the water managers from the highest population utilities knowing about the act, compared to less than half and one third of water utilities from the low and medium population categories respectively.

Insert Table 1 here.

In total, 504 innovations were identified by the interviewees in 37 different categories (Table 2). The most frequently conducted innovations (over 70%) were infrastructure-based and incremental in nature, and focused mainly on water treatment systems (11%), wastewater systems (10%), distribution lines (10%), pump and lift systems (9%), water storage facilities (8%), and non-smart meter replacements (5%). A further 10 percent were infrastructure-based but radical in nature, including smart meter installations, water reuse and recycling systems, public irrigation projects, and water efficient building designs. An additional 10 percent were institutional innovations that were incremental in nature, including water audit programs, the creation of water infrastructure master plans, infrastructure quality evaluation studies, public education programs, and employee training programs. The remaining nine percent were radical institutional innovations, including securing additional water rights or sources, water restrictions and conservation plans, water rate increases and restructuring, and new business models to change how the water utility operates.

Insert Table 2 here.

Interviewees identified and described the use of 34 dynamic capabilities, on average, per water utility. These dynamic capabilities led to an average of 13 innovations per utility. A summary of the descriptions and categorizations of the dynamic capabilities uncovered in this study can be found in Table 3 (sensing), Table 4 (seizing) and Table 5 (reconfiguring).

Sensing capabilities were the most frequently identified (average of 20 per utility, or 61% of total dynamic capabilities), followed by seizing (average of eight per utility, or 23%) and reconfiguring (average of five per utility, or 16%). Sensing capabilities helped managers anticipate future directions of the industry, recognize the benefits of new technologies and processes, and reduce risks from various stressors their utilities faced. The most frequent included drawing upon connections with external organizations (146 occurrences), enhancing water supply and conservation (101), activities to reduce vulnerability or risks (85), and actions focused on improving water efficiency (82) (Table 3).

Insert Table 3 here.

Municipalities that sensed the benefits of potential efficiency gains directed their efforts to developing innovations related to pump and lift stations (17% of the sample), the water treatment system (15%), and smart meters (14%). The sensing of water supply and conservation opportunities often targeted wastewater reuse projects (18%) and water system audits (12%). Sensing capabilities for infrastructure quality upgrades to reduce vulnerability or risks commonly involved water storage facilities (19%), the water distribution system (14%), and the water treatment system (11%). Sensing capabilities were at times utilized in pairs for particular infrastructure innovations. For example, sensing for cost savings/increased revenue often coexisted with sensing for efficiency benefits in smart meter installations. With respect to the pursuit of additional water sources and supply, municipalities sensed for knowledge related to both growth accommodation and water supply conservation.

Seizing capabilities were found as management acted upon sensed opportunities or reconfigured existing capabilities. Seizing and reconfiguring capabilities were both used to target new treatment plants, business models, and strategic planning within utilities seeking to increase the value of the public water system. Seizing included the creation of contingency funds (10% of the sample), water treatment system innovations (9%), and research studies (9%) (Table 4).

Insert Table 4 here.

Reconfiguring capabilities were identified as managers expressed openness to new technologies, processes, and forms of business that involved higher risk ventures and strategic planning. Utilities exhibited reconfiguring capabilities that led to strategic planning innovations (26% of the sample), smart meters (12%), water treatment systems (11%), and wastewater reuse infrastructure (8%) (Table 5).

Many innovations were related to the number of external organizations (an external dynamic capability), where high innovator utilities averaged five external organizations in comparison to low innovators averaging three. The most frequently utilized external organizations were universities, third-party engineering organizations, the Oklahoma Rural Water Association, and the Oklahoma Water Resources Board. These groups provided necessary resources such as expertise, funding, and labour, to aide municipalities in the innovation process.

Insert Table 5 here.

A series of multiple linear regression models revealed a relationship between the number of dynamic capabilities and the number of innovations by type, respectively (Table 6 and Table 7). Innovations created are dependent variables and total dynamic capabilities, population size, average income, Water 2060 awareness, and licensure level are the independent variables for these models. The inclusion of control variables provides for an examination of the effects they may have on the incidence of innovation. The intent of the controls is to determine if they influence water municipalities during transitions with significant effect.

Findings generally support the prevailing notion that availability of dynamic capabilities will increase the incidence of innovations in an organization, as noted in literature (Eisenhardt and Martin, 2000; Chen et al., 2015; Michailova and Zhan, 2015; Weerawardena et al., 2015; Forés and Camisón, 2016; Lin et al., 2016). For models constructed, coefficient values and their respective significance levels represent the magnitude and direction of influence each independent variable had per unit increase/decrease on the expression of the innovation counts at municipal water organizations. For example, 75 percent of the variation in innovations was explained in the case of Model #1. For this model, the total count of dynamic capabilities at an organization had a significant effect (at the $p < 0.001$ level, a 99.9% level of confidence that relationships established are not the result of random chance) on the total count of innovations at a given organization (Table 6). None of the controls were significant in the case of Model #1, suggesting total dynamic capabilities count is an effective predictor for total innovations at an organization. Interesting relationships were also suggested concerning the effects of certain controls on type-specific innovation counts. For example in Model #2 the positive condition for the binary situation of water manager awareness of the Water for 2060 legislation is associated with a 2.43 units gain in incremental innovations. The effect of water manager awareness of Water for 2060 in the case of

Model #2 is significant with 90% confidence. It seems, given the data and model results, that dynamic capabilities almost always have a significant effect on the expression of innovations, and that water manager knowledge of Water for 2060 legislation is also often significant. Other control variable significance was sporadic. This suggests that water managers may have more impact on the number of innovations created than factors such as population served, or the average income of that population. Sensing (Model #9) and seizing (Model #14) dynamic capabilities were more strongly related with infrastructure-oriented innovations than reconfiguring capabilities (Model #19), while reconfiguring capabilities were more strongly related with institutional innovations (Model #20). Seizing capabilities were strongly related to incremental innovations, while having knowledge of the Water for 2060 Act is associated with an additional 2.35 units gain in incremental innovations in Model #12 at a 90% confidence interval. Comparing models reveals that sensing (Model #8) and reconfiguring (Model #18) dynamic capabilities explained more of the variation in radical innovations than seizing (Model #13) (Table 6 and Table 7). These findings support studies that suggested the type of innovations relate to the type of dynamic capabilities (e.g. Forés and Camisón, 2016; Lieberherr and Truffer, 2015).

Insert Table 6 and Table 7 here.

Population size was found to be significant in the creation of institutional innovations (Model #5, Model #10, Model #15, Model #18), although the magnitude of the coefficient was generally small in its impact on innovation counts, with per-unit increases in population effecting changes in innovation counts on the order of millionths of one unit. Consequently, a change in innovation count given these models could be expected with the addition of approximately one million residents to a water organizations user base. Average household income was significant to prediction of infrastructure innovations when sensing dynamic capabilities (Model #9) and reconfiguring dynamic capabilities (Model #19) were significant also.

The level of licensure of the water manager did not have any significant effect on innovations in any of the models constructed. This suggests that the level of water manager training is not a reliable predictor in the number of innovations created in water utilities. On the other hand, awareness of the Water for 2060 Act was significant in predicting the number of incremental innovations created by water utilities when sensing (Model #7) and seizing dynamic capabilities (Model #12) were significant, and when reconfiguring dynamic capabilities were not significant (Model #17). This suggests that the Water for 2060 Act and its supporting networks and resources are important to incremental innovations even when reconfiguring dynamic capabilities are not present. Knowledge of the Water for 2060 Act was important to the number of infrastructure innovations created, however, when reconfiguring dynamic capabilities were significant (Model #19).

5.0 Conclusion

This study contributes to the dynamic capabilities literature on public water utilities undertaking innovation. The first key finding suggests that water system innovation as measured by the number of innovations created and implemented is related to the number and use of dynamic capabilities. This supports previous studies that identified dynamic capabilities as key factors in the innovation process in water utilities (Lieberherr and Truffer, 2015) and other organizations (Eisenhardt and Martin, 2000; Chen et al., 2015; Michailova and Zhan, 2015; Weerawardena et al., 2015; Forés and Camisón, 2016; Lin et al., 2016). The second finding is the identification of differences in the strength of the relationships between sensing, seizing and reconfiguring dynamic capabilities, and radical and incremental innovations. This helps understand "the processes and components in a system where intervention is likely to matter most" to sustainability transitions (Jacobsson and Bergek, 2011, p. 41). The third finding is that the majority of innovations were infrastructure-incremental, supporting the need for more radical innovations if transitions are going to occur in Oklahoma. Fourth, seizing capabilities were strongly related to incremental innovations, while Oklahoma's water utilities employed many of the same sensing capabilities identified by Lieberherr and Truffer (2015). Fifth, since license level of the water manager is not a reliable predictor of innovation, perhaps the individual water manager's dedication or personality are of greater impact than formal education in terms of serving the public, a question for future research. Finally, the importance of water manager awareness of the Water for 2060 Act to the creation of innovations in water utilities was evident. This suggests that Water for 2060 programs are catching on or are beginning to have an impact on at least the decision-making of water managers. These findings lead to a series of recommendations for improving the effectiveness of attempts to influence water system innovation.

The first recommendation is to support the provisions in the Water for 2060 Act, which include creating a coordinator and accompanying web-portal to serve as a central hub for facilitating financial, knowledge sharing, and learning capabilities for water efficiency and innovation (OWRB, 2012b; OWRB, 2015a). The hub will increase the level of coordination and thus external dynamic capabilities between water utilities, and organizations including the American Water Works Association, the WaterReuse Association, the Environmental Protection Agency's WaterSense program, the Oklahoma Department of Environmental Quality, the Oklahoma Municipal League, and other state and federal agencies. The Water for 2060 Act has the potential to enable water system innovation by facilitating the use of dynamic capabilities through participation of new organizations, forming social and learning networks, creating a new alignment of institutions for multi-level governance, supporting the accumulation and diffusion of knowledge, and encouraging experimentation.

The second recommendation is to focus on developing sensing and reconfiguring dynamic capabilities, which were strongly related to radical innovations. Reconfiguring dynamic capabilities in particular can be aided by the public awareness and communication plan of Water for 2060, with its focus on radical innovations like wastewater reuse systems. A recommendation of Water for 2060 to increase regional water sharing within the state would require radical infrastructure innovations as well as new institutional and governance innovations to overcome the contested water system dynamics that have long characterized Oklahoma (OWRB, 2015a).

The third recommendation is to improve water utilities' access to state funding options by helping utilities develop a business case and strategic planning for water efficiency and infrastructure changes. These seizing and reconfiguring capabilities will help utilities mobilize resources and public support for expensive infrastructure changes and politically contentious institutional changes. If Oklahoma is to accomplish the goals set forth in Water for 2060, utilities can foster dynamic capabilities by supporting leaders as well as organizational cultures and structures that promote creativity and learning (Teece and Pisano, 1994; Zollo and Winter, 2002; Teece, 2007; Ambrosini et al., 2009).

Water utilities benefit from innovation, cost savings, and public goods accrued from capacity development and resiliency of the water system. Therefore, future research should examine the effectiveness of a proposed competition and reward system based on efficiency improvements at spurring the development of dynamic capabilities for innovation in Oklahoma's municipal and rural water systems. Additionally, researchers should evaluate the Water for 2060 central water hub for its role in helping water managers scan for issues and opportunities, and increasing collaboration with agricultural and energy water users. A multi-year study could help to understand the effectiveness of these enabling and engagement functions at supporting and encouraging water managers to co-develop and deploy new seizing and reconfiguring capabilities. Creating change through innovation and developing the capacity to create change (e.g. dynamic capabilities) are both critically important to water system sustainability in the face of climate changes and funding uncertainties that only increase the vulnerability of water supply.

Acknowledgements

The authors thank the interviewees for their time and insightful contributions to this research. The authors would also like to thank our research assistant Martin Koch for his diligent work helping to recruit interviewees, and Mark Shafer for his support and feedback throughout the research process. The authors also greatly appreciate the constructive and insightful suggestions of the anonymous referees. This study was funded by a grant from the NOAA Regional Integrated Sciences and Assessment (RISA) Program from NOAA's Climate Program Office under co-operative agreement NA13OAR4310183.

References

Ajami, N. K., Thompson, B. H., Victor, D. G., 2014. The Path to Water Innovation. Stanford Digital Repository. http://purl.stanford.edu/ny029hr5774 (accessed 23.04.15).

Albury, D., Mulgan, G., 2003. Innovation in the Public Sector. HM Government Paper, Prime Minister's Strategy Unit, London.

Allen, S., 2015. Western Oklahoma Cities Look to Conserve Water Amid Drought. http://newsok.com/western-oklahoma-cities-look-to-conserve-water-amid-drought/article/5399400 (accessed 15.06.15).

Ambrosini, V., Bowman, C., Collier, N., 2009. Dynamic capabilities: An exploration of how organizations renew their resource base. Br. J. of Manag., 20 (1), 9-24.

American Society of Civil Engineers, 2013. Infrastructure Report Card. 2013 Report Card for Oklahoma's Infrastructure. http://www.infrastructurereportcard.org/oklahoma/oklahoma-overview/ (accessed 13.12.14)

Arend, R. J., 2015. Mobius' edge: Infinite regress in the resource-based and dynamic capabilities views. Strategic Organ., 13 (1), 75–85.

Ashley, R., Blackwood, D., Butler, D., Jowitt, P., Davies, J., Smith, H., ... & Oltean-Dumbrava, C., 2008. Making asset investment decisions for wastewater systems that include sustainability. *Journal of Environmental Engineering*, 134(3), 200-209.

Bekkers, V.J.J.M., Tummers, L.G., Voorberg, W.H., 2013. From Public Innovation to Social Innovation in the Public Sector: A Literature Review of Relevant Drivers and Barriers. Rotterdam: Erasmus University Rotterdam.

Borins, S., 2002. Leadership and innovation in the public sector. Leadersh. & Organ. Dev. J., 23 (8), 467-476.

Cachia, M., Millward, L., 2012. The telephone medium and semi-structured interviews: a complementary fit. Qual. Res. in Organ. and Manag.: An Inter. J., 6 (3), 265-277.

Chen, Y. S., Lin, Y. H., Lin, C. Y., Chang, C. W., 2015. Enhancing green absorptive capacity, green dynamic capacities and green service innovation to improve firm performance: An analysis of structural equation modeling (SEM). Sustainability, 7 (11), 15674-15692.

Clifford, S., n.d.. Tipsheet- Interviewing Elites. http://www.dism.ssri.duke.edu/pdfs/Tipsheet - Elite Interviews.pdf (accessed 04.01.2014)

Cromwell, J., Speranza, E., Reynolds, H, 2001. Reinvesting in Drinking Water Infrastructure: Dawn of the Replacement Era. Denver, CO: AWWA.

Damanpour, F., Schneider, M., 2009. Characteristics of innovation and innovation adoption in public organizations: Assessing the role of managers. J. of Publ. Adm. Res. and Theory, 19 (3), 495–522.

Devinney, T. M., 2013. Is microfoundational thinking critical to management thought and practice? The Academy of Manag. Perspect., 27 (2), 81-84.

Oklahoma Department of Environmental Quality, 2015. Operator Certification Section. State of Oklahoma Distribution and Collection Manual. Oklahoma Department of Environmental Quality. http://www.deq.state.ok.us/pubs/wqd/distribution-collection_study_guide.pdf (accessed 08.05.2015)

Easterby-Smith, M., Lyles, M. A., Peteraf, M. A., 2009. Dynamic capabilities: current debates and future directions. Br. J. of Manag., 20 (1), 1-8.

Eisenhardt, K. M., Martin, J. A., 2000. Dynamic capabilities: what are they? Strategic Manag. J., 21 (10-11), 1105-1121.

Felin, T., Foss, N. J., 2005. Strategic organization: a field in search of micro-foundations. Strategic Organ., 3 (4), 441–455.

Foss, N. J., Heimeriks, K. H., Winter, S. G., Zollo, M, 2012. A hegelian dialogue on the micro-foundations of organizational routines and capabilities. Euro. Manag. Rev., 9 (4), 173–197.

Foss, N. J., Lindenberg, S., 2013. Microfoundations for strategy: A goal-framing perspective on the drivers of value creation. The Acad. of Manag. Perspect., 27 (2), 85-102.

Forés, B., Camisón, C., 2016. Does incremental and radical innovation performance depend on different types of knowledge accumulation capabilities and organizational size? J. of Bus. Res., 69 (2), 831-848.

Gaziulusoy, A. I., 2015. A critical review of approaches available for design and innovation teams through the perspective of sustainability science and system innovation theories. J. of Clean. Prod., 107, 366–377.

Gliedt, T., Parker, P., 2010. Dynamic capabilities for strategic green advantage: Green electricity purchasing in North American firms, SMEs, NGOs and agencies. Glob. Bus. and Econ. Rev., 12(3), 171-195.

Harvey, W. S., 2011. Strategies for conducting elite interviews. Qual. Res., 11 (4), 431-441.

Helfat, C., Peteraf, M., 2009. Understanding dynamic capabilities: progress along a developmental path. Strategic Organ., 7 (1), 91.

Helfat, C. E., Winter, S. G., 2011. Untangling dynamic and operational capabilities: strategy for the (N) ever-changing world. Strategic Manag. J., 32 (11), 1243–1250.

Hering, J. G., Waite, T. D., Luthy, R. G., Drewes, J. E., Sedlak, D. L., 2013. A changing framework for urban water systems. Environ. Sci. & Tech., 47 (19), 10721-10726.

Hornberger, G. M., Hess, D. J., Gilligan, J., 2015. Water conservation and hydrological transitions in cities in the United States. Water Resourc. Res., 51, 4635–4649.

International Water and Climate Forum (IWCF), 2016. Adapt, Mitigate, Evolve. Synthesis Report. Association of Metropolitan Water Agencies. http://www.waterclimateforum.org/forum-synthesis-report-issued/ (accessed 14.03.16).

Jacobsson, S., Bergek, A., 2011. Innovation system analyses and sustainability transitions: Contributions and suggestions for research. Environ. Innov. and Soc. Transit, 1 (1), 41-57.

Karl, T.R., Melillo, J.M., Peterson, T.C., eds., 2009. Global Climate Change Impacts in the United States. Cambridge University Press: New York.

Kearney, R. C., Feldman, B. M., Scavo, C. P., 2000. Reinventing government: City manager attitudes and actions. Public Admin. Rev., 60 (6), 535-548.

Kiparsky, M, et al., 2013. The innovation deficit in urban water: the need for an integrated perspective on institutions, organizations, and technology. Environ. Eng. Sci. 30 (8), 395–408.

Krozer, Y., Hophmayer-Tokich, S., van Meerendonk, H., Tijsma, S., Vos, E., 2010. Innovations in the water chain–experiences in The Netherlands. J. of Clean. Prod., 18(5), 439-446.

Lawson, B., Samson, D., 2001. Developing innovation capability in organisations: a dynamic capabilities approach. Int. J. of Innov. Manag., 5 (3), 377-400.

Leavy, P., ed., 2014. The Oxford Handbook of Qualitative Research. Oxford University Press.

Lemos, M. C., 2008. What Influences Innovation Adoption by Water Managers? Climate Information Use in Brazil and the United States. J. of the Am. Water Resour. Assoc., 44 (6),1388- 1396.

Lepoutre J., 2008. Proactive environmental strategies in small businesses: Resources, institutions and dynamic capabilities. Dissertation, Ghent University, Belgium.

Lieberherr, E., Truffer, B., 2015. The impact of privatization on sustainability transitions: A comparative analysis of dynamic capabilities in three water utilities. Environ. Innov. and Soc. Transit., 15 (1), 101-122.

Lienert, J., Scholten, L., Egger, C., & Maurer, M., 2015. Structured decision-making for sustainable water infrastructure planning and four future scenarios. *EURO Journal on Decision Processes*, 3(1-2), 107-140.

Lin, H. F., Su, J. Q., Higgins, A., 2016. How dynamic capabilities affect adoption of management innovations. J. of Bus. Res., 69 (2), 862-876.

Michailova, S., Zhan, W., 2015. Dynamic capabilities and innovation in MNC subsidiaries. J. of World Bus., 50 (3), 576-583.

Mikecz, R., 2012. Interviewing elites addressing methodological issues. Qual. Inq., 18 (6), 482-493.

Moore, D. S., 2000. The Basic Practice of Statistics, 2nd ed. New York, Freeman and Company.

Narayanan, V. K., Colwell, K., Douglas, F. L., 2009. Building organizational and scientific platforms in the pharmaceutical industry: a process perspective on the development of dynamic capabilities. Br. J. of Manag., 20 (1), 25-40.

Oklahoma Climatological Survey, 2012. Normal Annual Precipitation. http://climate.ok.gov/index.php/climate/map/normal_annual_precipitation/oklahoma_climate (accessed 08.08.15).

Oklahoma Mesonet System (Mesonet), 2015. Oklahoma Climatological Survey. http://www.mesonet.org/ (accessed 08.08.2015).

Oklahoma Water Resources Board (OWRB), 2012a. Hydrologic Drought of Water Year 2011: A Historical Context. Oklahoma Water Resources Board. http://www.owrb.ok.gov/supply/drought/pdf_dro/DroughtFactSheet2011.pdf (accessed 04.05.15).

Oklahoma Water Resources Board (OWRB), 2012b. Oklahoma Comprehensive Water Plan: Central Watershed Planning Region Report, ver 1.1. https://www.owrb.ok.gov/supply/ocwp/pdf_ocwp/WaterPlanUpdate/regionalreports/OCWP_Central_Region_Report.pdf (accessed 06.04.14).

Oklahoma Water Resources Board (OWRB), 2013. Oklahoma Emergency Drought Commission and Relief Fund. Oklahoma Water Resources Board. http://www.owrb.ok.gov/news/news2/pressrelease2014.php#032014 (accessed 04.05.15).

Oklahoma Water Resources Board (OWRB), 2014a. Water for 2060 Status Report. https://www.owrb.ok.gov/2060/2060statusrpt.pdf (accessed 04.05.15).

Oklahoma Water Resources Board (OWRB), 2014b. Water Resources Bulletin. Oklahoma Water Resources Board.

https://www.owrb.ok.gov/supply/drought/pdf_dro/2014/314_1226_2014.pdf (accessed 04.05.15).

Oklahoma Water Resources Board (OWRB), 2014c. Water for 2060 Drought Grants. Financial Assistance and Project Eligibility. Oklahoma Water Resources Board. https://www.owrb.ok.gov/financing/grant/droughtgrants.php (accessed 04.05.15).

Oklahoma Water Resources Board (OWRB), 2015a. Final Report of the Water for 2060 Advisory Council. Oklahoma Water Resources Board. https://www.owrb.ok.gov/2060/2060Recommendations.pdf (accessed 29.12.15).

Oklahoma Water Resources Board (OWRB), 2015b. Water News: Tulsa Metropolitan Utility Authority Receives $21,000,000 OWRB Loan Approval for Several Wastewater System Improvements. http://www.owrb.ok.gov/news/news2/pressrelease2014.php#032014 (accessed 02.03.16).

Oklahoma Water Resources Board (OWRB), 2015c. Water News: Water for 2060 Grants Awarded. https://www.owrb.ok.gov/news/news2/pdf_news2/WaterNews/WaterNews2015-1.pdf (accessed 04.05.15).

Oklahoma Water Resources Board (OWRB), 2016. Oklahoma's Water for 2060 Initiative Featured at White House Water Summit. http://www.owrb.ok.gov/news/news2/pressreleases/2016/032216.php (accessed 03.25.16)

Opdenakker, R., 2006. Advantages and disadvantages of four interview techniques in qualitative research. Forum: Qual. Soc. Res. Sozial, 3 (2). http://www.qualitative-research.net/index.php/fqs/article/view/865 (accessed 03.03.2016).

O'Reilly III, C. A., Tushman, M. L., 2008. Ambidexterity as a dynamic capability: Resolving the innovator's dilemma. Res. in Organ. Behav., 28, 185-206.

Pahl-Wostl, C., 2007. Transitions towards adaptive management of water facing climate and global change. Water Resour. Manag., 21 (1), 49-62.

Potts, J., 2009. The innovation deficit in public services: The curious problem of too much efficiency and not enough waste and failure. Innov.: Manag., Policy & Prac., 11 (1), 34–43.

Scholten, L., Schuwirth, N., Reichert, P., & Lienert, J., 2015. Tackling uncertainty in multi-criteria decision analysis–An application to water supply infrastructure planning. *European Journal of Operational Research*, 242(1), 243-260.

Spiller, M., McIntosh, B. S., Seaton, R. A., Jeffrey, P. J., 2015. Integrating process and factor understanding of environmental innovation by water utilities. Water Resour. Manag., 29 (6), 1979-1993.

Sheskin, D. J., 2011. Handbook of Parametric and Nonparametric Statistical Procedures, 5th ed. Chapman and Hall: Boca Raton, FL.

Subramaniam, M., Youndt, M. A., 2005. The influence of intellectual capital on the types of innovative capabilities. Acad. of Manag. J., 48 (3), 450-463.

Teece, D., Pisano, G., 1994. The dynamic capabilities of organizations: an introduction. Ind. and Corp. Change, 3 (3), 537-556.

Teece, D. J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strategic Manag. J., 18 (7), 509-533.

Teece, D. J. (2007). Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. Strategic Manag. , 28(13), 1319-1350.

Thenint, H., 2010. Mini Study 10: Innovation in the Public Sector. Global Review of Innovation Intelligence and Policy Studies. Inno Grips. http://grips.proinno-europe.eu/knowledge_base/dl/889/orig_doc_file/ (accessed 04.03.2016).

United States Department of Agriculture (USDA), 2016. Geospatial Data Gateway. https://gdg.sc.egov.usda.gov (accessed 02.02.16)

Weerawardena, J., Mort, G. S., Salunke, S., Knight, G., Liesch, P. W., 2015. The role of the market sub-system and the socio-technical sub-system in innovation and firm performance: a dynamic capabilities approach. J. of the Acad. of Mark. Sci., 43 (2), 221-239.

Welsh, E., 2002. Dealing with data: Using NVivo in the qualitative data analysis process. Forum: Qual. Soc. Res. Sozial, 3 (2). http://www.qualitative-research.net/index.php/fqs/article/view/865 (accessed 03.03.2016).

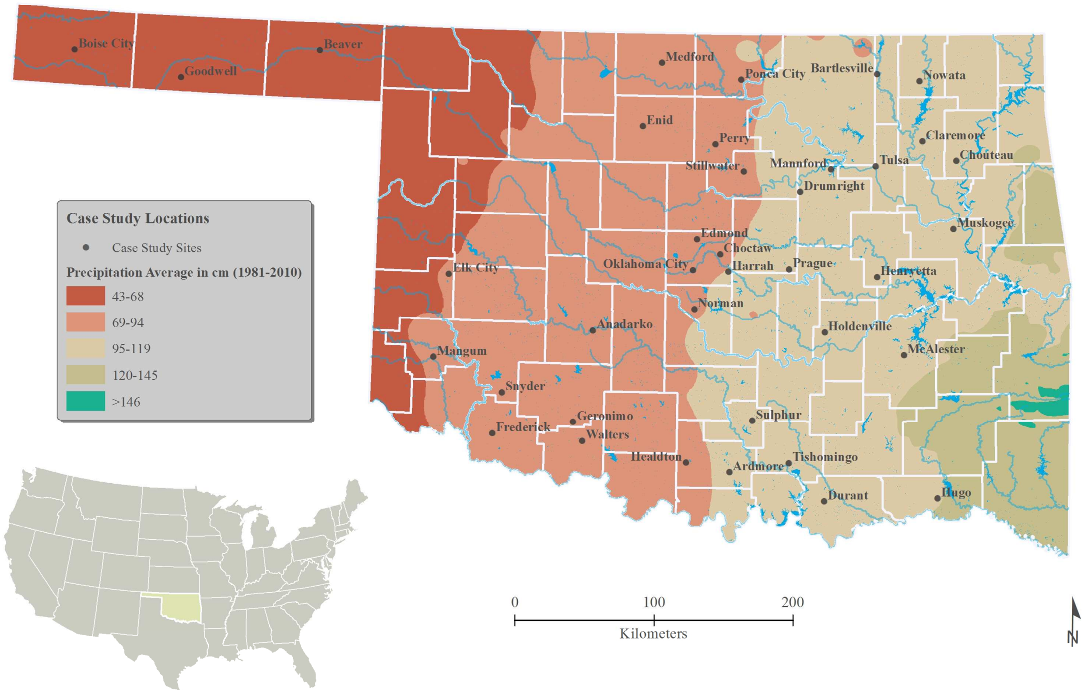
Widener, J.M., Gliedt, T.J., Hartman, P., 2016. Visualizing dynamic capabilities as adaptive capacity for municipal water governance. Sustain Sci. doi:10.1007/s11625-016-0408-y.

Winter, S. G., 2003. Understanding dynamic capabilities. Strategic Manag. J., 24 (10), 991-995.

Zahra, S. A., Sapienza, H. J., Davidsson, P., 2006. Entrepreneurship and dynamic capabilities: a review, model and research agenda. J. of Manag. Stud., 43 (4), 917-955.

Zollo, M., Winter, S. G., 2002. Deliberate learning and the evolution of dynamic capabilities. Organ. Sci., 13 (3), 339-351.

Figure 1: Normal Annual Precipitation for Oklahoma



Source: Map showing the 38 case study sites as well as Oklahoma's 30-year precipitation average (USDA, 2016) [cartography by JMW].

Table 1: Summary Statistics Organized by Population Categories n = 38

	Population Categories		
	<5,000	5,000-40,000	>40,000
n	17	15	6
Avg. # of Dynamic Capabilities per Utility	27	29	64
Standard Deviation	8	12	22
Avg. # of Innovations per Utility	11	11	25
Standard Deviation	4	5	6
Average Household Income	37,366	40,626	46,799
Standard Deviation	6,366	9,883	12,226
Average Population	2,481	15,620	209,884
Standard Deviation	1,078	10,897	203,772
Median Licensure Level of Water Manager	2	3	4
Variance	0.61	0.60	0.00
% of Water Managers with Knowledge of Water for 2060	47	33	83
Variance	0.26	0.24	0.17

Note: The licensure level of water managers ranged from the lowest levels of D, C, B, to the highest levels of A and professional engineer (PE). The A and PE were combined into a single category to reflect the highest level of water manager training available in Oklahoma. These levels were then coded for analysis as follows: D=1, C=2, B=3, APE=4. The APE category represents superior educational training and expertise as described by the Oklahoma Department of Environmental Quality (Department of Environmental Quality, 2015). The requirements for certification increase as you move up the licensure levels. This relates to both the training and level of experience. For example, a D level operator has 16 hours of approved Department of Environmental Quality approved training, while an A level operator has 200 hours of approved training, including at least 40 hours of Department of Environmental Quality approved courses in advanced treatment and managerial training. The A level operator must also have at least five years of water works or wastewater works operational experience including two years of hands-on operating experience (Department of Environmental Quality, 2015, p. iv).

Table 2: Innovation Types and Categorizations for n = 38

Innovation Types	# of Innovations	% of total	Infrastructure or Institutional	Radical or Incremental
Water Treatment System	55	10.9%	Infrastructure	Incremental
Waste Water System	49	9.7%	Infrastructure	Incremental
Distribution Lines/System	49	9.7%	Infrastructure	Incremental
Pump & Lift Stations	46	9.1%	Infrastructure	Incremental
Water Storage Facilities	38	7.5%	Infrastructure	Incremental
Non-Smart Meter Replacements	25	5.0%	Infrastructure	Incremental
Smart Meter Installation	23	4.6%	Infrastructure	Radical
New Wells/Retrofit of Existing	21	4.2%	Infrastructure	Incremental
Valves	19	3.8%	Infrastructure	Incremental
Raw Water Lines (Source)	19	3.8%	Infrastructure	Incremental
Water Reuse & Recycle	16	3.2%	Infrastructure	Radical
Basic Maintenance Programs	14	2.8%	Infrastructure	Incremental
Additional Water Rights/Sources	14	2.8%	Institutional	Radical
Water Audit	11	2.2%	Institutional	Incremental
Water Restrictions/Conservation Plans	11	2.2%	Institutional	Radical
Water Rate Increases/Restructuring	11	2.2%	Institutional	Radical
Water Infrastructure and Source Plans (Master Plans)	10	2.0%	Institutional	Incremental
Stormwater System	9	1.8%	Infrastructure	Radical
Infrastructure Evaluation Study	9	1.8%	Institutional	Incremental
Business Model	9	1.8%	Institutional	Radical
Generators	6	1.2%	Infrastructure	Incremental
Public Irrigation	4	0.8%	Infrastructure	Radical
Efficient Building Design	4	0.8%	Infrastructure	Radical
Research Studies	4	0.8%	Institutional	Incremental
Public Education Programs	4	0.8%	Institutional	Incremental
Cross Training (Employees)	4	0.8%	Institutional	Incremental
New Use of Wells	3	0.6%	Infrastructure	Incremental
Smart Meter Replacement	3	0.6%	Infrastructure	Radical
Security Measures	2	0.4%	Infrastructure	Incremental
Fire Hydrants	2	0.4%	Infrastructure	Incremental
Use of Livestock	2	0.4%	Infrastructure	Radical
Water Table/Well Audit	2	0.4%	Institutional	Incremental
Internal Employee Learning/Training	2	0.4%	Institutional	Incremental
Meters in New Areas	1	0.2%	Infrastructure	Incremental
Dam Construction	1	0.2%	Infrastructure	Incremental
Safety Training	1	0.2%	Institutional	Incremental
Use of Private Water Operators	1	0.2%	Institutional	Incremental
TOTAL	**504**	**100%**		

Table 3: Use of Sensing Dynamic Capabilities for n = 38

Focus Area for Sensed Opportunity	Sensing Component of Dynamic Capability	# of Times Sensing Used	%
External Organizations	Utilizing external organizations and their knowledge and resources (funding, knowledge, etc.).	146	18.8
Water Supply & Conservation	Sensing the need to protect, maintain, and conserve water resources.	101	13.0
Risk Reduction	Seeking to reduce risks to the water system, safety of the public, or the organization and its employees.	85	11.0
Efficiency	Sensing the benefits of efficiency gains through product or service offerings (reduction in man power, reduced impacts on water system, etc.).	82	10.6
Infrastructure Quality Upgrades	Sensing the need to update and replace outdated and or poor quality infrastructure items.	65	8.4
Growth Accommodation	Sensing the need to account for future population and or economic growth in decision-making.	59	7.6
Cost Savings	Sensing projects for the benefit of reduced cost savings through operating activities.	50	6.4
Regulatory Compliance	Sensing the future changes and modifications to regulatory standards that could affect the water system.	31	4.0
Internal Education & Learning	Training that occurs within the organization through formal and informal means (training by upper management, vendors, on the job training, safety training, etc.).	29	3.7
External Training	Non-mandated training conducted outside the municipality (seminars, workshops, conferences, etc.).	28	3.6
Basic Maintenance Programs	Sensing the need for continued maintenance on infrastructure items.	24	3.1
Increased Revenue	Sensing the ability to increase the water system's financial resources.	20	2.6
Drought	Sensing the effects or potential effects and consequences of drought.	15	1.9
Grants	Sensing the ability to pursue and utilize external sources of funding.	16	2.1
Financial Opportunities	Sensing opportunities to gain financial resources or reduce financial burdens for current and future projects (loan restructuring, issuing of bonds, tax increases, etc.).	11	1.4
Inter-generational Equity	Sensing increased benefits for future generations.	5	0.6
Social Capital	Sensing and utilizing knowledge and expertise from industry professionals, colleagues, and other municipalities.	5	0.6
Stakeholder Concerns	Taking citizen concerns, thoughts, and ideas into consideration for current and future projects.	2	0.3
Public Health	Sensing the need to protect, maintain, or increase the quality health standards.	1	0.1
Publications	Utilizing various publications for decision-making (academic, newspaper, etc.)	1	0.1
		776	100

Table 4: Use of Seizing Dynamic Capabilities for n = 38

Focus Area for Seizing	Seizing Component of Dynamic Capability	# of Times Seizing Used	%
Contingency Funds	Reserve funds created by municipalities to utilize for emergencies or large capital expenditures.	29	9.8
Water Treatment System	Renovations/replacements to the water treatment facility.	27	9.1
Research	Conducting research internally or in combination with organizations to assess a given project, new form of technology, process, or service.	26	8.8
Water System Auditing (Non-Well)	Determining water loss within the treatment and distribution systems.	22	7.4
Pumping/Lift Stations	Replacement of materials, pumps, etc. for pumping and lift stations.	19	6.4
Basic Maintenance Programs	Conducting continued maintenance on infrastructure items (water storage facilities, pump stations, etc.)	18	6.1
Waste Water Treatment System	Renovations/replacements to the waste water treatment facilities and collection systems.	15	5.1
Water Line Distribution System	Replacing portions of water distribution lines that deliver treated water to end-users.	14	4.7
Smart Meters	Non-traditional water meters with abilities such as drive by metering, automatic meter reading, leak detection, etc.	14	4.7
Water Storage Facilities	Renovations/replacements of water storage facilities (above and below ground towers, stand pipes, etc.)	13	4.4
New/Retrofit Wells	The drilling of new or significant retrofits of existing water wells to ensure the reliability of municipal water sources.	13	4.4
Business Model Restructuring	New organizational structures/departments, taking advantage of new financial structures (bonds, re-financing, taxes etc) and new business opportunities (selling water to new industry).	10	3.4
Water Restrictions/Conservation Plans	Plans designed to reduce the consumption of treated water resources by end-users.	10	3.4
Rate Increases/Study	Increasing the financial rates for public water consumption or conducting studies to assess feasibility or need for current/future rate increases.	8	2.7
Infrastructure Evaluation Study	Strategic studies to evaluate the condition and current/future needs of the municipal water system.	5	1.7
Master Plans (Strategic Planning)	Long-term infrastructure plans designed to update and replace infrastructure and water system processes over a given time frame. Includes strategic planning in the process.	8	2.7
Additional Water Rights/Sources	Obtaining the legal rights to pursue additional surface, groundwater, or purchased water sources.	4	1.3
Non-Smart Meter	The replacement of individual water meters to new and more accurate traditional water meters.	7	2.4
Public Irrigation	Projects to retrofit existing public irrigation systems with recycled water (grey water, waste water, lower qualities of treated water etc.).	4	1.3
Stormwater System	Renovations/replacements made to the stormwater collection system.	4	1.3
Efficient Building Design	Constructing new public buildings with more efficient technologies (water efficient, geothermal, etc.).	3	1.0
Employee Cross Training	Training employees to be able to work across different departments or job functions.	3	1.0
Innovative Internal Training	Internal employee training mechanisms that were voluntarily created by utility personnel to increase understanding of the water/waste water treatment and collection systems.	2	0.7
Source Lines	Renovations/replacements of raw water lines from the water source to treatment facilities.	3	1.0
Well-Water Auditing	Auditing the water table levels by examining withdrawal rates of groundwater sources.	3	1.0
Generators	Implementing generators for back up energy supply to maintain system functionality.	3	1.0
Public Education Programs	Educational programs designed to increase public knowledge of water/waste water processes (plant tours, public education programs, etc.).	2	0.7
Security Systems & Measures	The installation of security mechanisms or measures (cameras, fences, etc.).	2	0.7
Valves	Renovations/replacements to valves in the water system.	2	0.7
Fire Hydrants	Replacing existing fire hydrants in the system.	1	0.3
Safety Training Innovations	Safety training sessions that have occurred in the last 5 years.	1	0.3
Use of Livestock	Utilizing livestock for specific projects to accrue benefits for a system, service, or process.	1	0.3
Water Reuse & Recycle	Innovations to utilize recycled water resources (wastewater, grey water, etc.).	1	0.3
		297	100

Table 5: Use of Reconfiguring Dynamic Capabilities for n = 38

Focus Area for Reconfiguring	Reconfiguring Component of Dynamic Capability	# of Times Reconfiguring Used	%
Strategic Planning	Strategic planning that is aimed to identify system deficiencies and spur the development of future projects.	52	25.9
Smart Meters	Willingness to adopt technologically advanced water meters with abilities such as drive by metering, automatic meter reading, leak detection, etc.	24	11.9
Water Treatment System	Willingness for new processes/replacements/superior technologies at the water treatment facilities/system.	21	10.4
Water Reuse & Recycle	Willingness to consider and engage in water reuse and recycle projects.	16	8.0
Additional Water Rights/Sources	Willingness to pursue and obtain additional water rights and sources.	15	7.5
Rate Study/ Increases	Willingness to adopt alternative rate structures/prices or conducting studies to determine feasibility of new rate structures/prices.	13	6.5
Pumps and Lift Stations	Willingness for new processes/replacements/superior technologies to the pump and lift stations. (e.g. variable frequency drives)	10	5.0
Water Restrictions/Conservation Plans	Willingness to adopt and create plans to reduce the consumption of treated water resources.	10	5.0
Alternative Business Model	Willingness to create and enact alternative business models (new departments/positions, new services, processes, bonds, taxes etc.)	6	3.0
Generators	Willingness to pursue reserve sources for power generation.	5	2.5
Waste Water Treatment System	Willingness for new processes/replacements/superior technologies to the wastewater treatment/collection system.	5	2.5
Public Education Programs	Willingness to implement public education campaigns to increase awareness of the water/waste water systems.	4	2.0
Public Irrigation	Willingness to manage public irrigation rates	4	2.0
New Use of Wells	Utilizing old/abandoned wells or diversifying water resources by pursuing groundwater resources.	3	1.5
Distribution Lines	Willingness for new processes/replacements/superior technologies to the distribution system.	2	1.0
Efficient Building Design	Willingness to utilize efficient technologies in new construction (Water efficient devices, geothermal, etc.)	2	1.0
Stormwater System	Willingness for new processes/replacements/superior technologies to the stormwater system.	2	1.0
Use of Livestock	Willingness to use livestock for specific projects.	2	1.0
Valves	Willingness for new processes/replacements/superior technologies to the water valves.	2	1.0
Water Storage	Willingness for new processes/replacements/superior technologies at the water storage facilities.	2	1.0
Meters in New Areas	Willingness to implement meters in areas that historically have not been metered.	1	0.5
		201	100

Table 6: Multiple Linear Regression Models 1-10 for Water Utility Innovation n = 38

Model #	1	2	3	4	5	6	7	8	9	10
Dependent Variable (Innovation Type)	Total Innovations	Incremental Innovations	Radical Innovations	Infrastructure Innovations	Institutional Innovations	Total Innovations	Incremental Innovations	Radical Innovations	Infrastructure Innovations	Institutional Innovations
Independent Variable (Dynamic Capability Type)	Total Dynamic Capabilities	Total Dynamic Capabilities	Total Dynamic Capabilities	Total Dynamic Capabilities	Total Dynamic Capabilities	Sensing Dynamic Capabilities	Sensing Dynamic Capabilities	Sensing Dynamic Capabilities	Sensing Dynamic Capabilities	Sensing Dynamic Capabilities
β Dynamic Capability Type	0.249264***	0.133966*	0.115299***	0.188823***	0.060441**	0.355616***	0.178409*	0.177207***	0.282342***	0.073274*
β Population Served	0.000003	0.000007	-0.000005	-0.000003	0.000006*	0.00001	0.000012	-0.000002	0.000002	0.000009**
β Average Household Income	0.000082	0.000063	0.000019	0.00008	0.000002	0.000128*	0.000089	0.000038	0.000113*	0.000015
β Licensure Level of Manager	0.766284	0.429195	0.33709	0.785936	-0.019652	1.082173	0.623053	0.459119	1.000687	0.081486
β Manager Aware of Water for 2060	2.122784	2.430745*	-0.30796	1.661466	0.461318	2.115023	2.49159*	-0.376567	1.589341	0.525682
β Constant	-3.787125	-1.559049	-2.228076	-3.295527	-0.491597	-5.729692	-2.60157	-3.128122*	-4.768591	-0.961101
Model R2	0.752	0.561	0.667	0.664	0.658	0.716	0.536	0.65	0.644	0.612
Std. Error of the Estimate	3.664	3.913	1.513	3.275	1.361	3.916	4.023	1.55	3.367	1.45
***: p< 0.001; **: p < 0.01; *: p < 0.10										

Table 7: Multiple Linear Regression Models 11-20 for Water Utility Innovation n = 38

Model #	11	12	13	14	15	16	17	18	19	20
Dependent Variable (Innovation Type)	Total Innovations	Incremental Innovations	Radical Innovations	Infrastructure Innovations	Institutional Innovations	Total Innovations	Incremental Innovations	Radical Innovations	Infrastructure Innovations	Institutional Innovations
Independent Variable (Dynamic Capability Type)	Seizing Dynamic Capabilities	Seizing Dynamic Capabilities	Seizing Dynamic Capabilities	Seizing Dynamic Capabilities	Seizing Dynamic Capabilities	Reconfiguring Dynamic Capabilities	Reconfiguring Dynamic Capabilities	Reconfiguring Dynamic Capabilities	Reconfiguring Dynamic Capabilities	Reconfiguring Dynamic Capabilities
β Dynamic Capability Type	1.04411***	0.704662***	0.339448**	0.793394***	0.250716**	0.882435**	0.37915	0.503286***	0.54666*	0.335775***
β Population Served	0.000001	0.000004	-0.000002	-0.000005	0.000006*	0.000002	0.000009	-0.000007*	-0.000001	0.000003
β Average Household Income	-0.00001	-0.000012	0.000003	0.00001	-0.00002	0.000121	0.00009	0.000031	0.000118*	0.000003
β Licensure Level of Manager	0.57723	0.165596	0.411635	0.639948	-0.062717	0.920402	0.602066	0.318336	1.017996	-0.097594
β Manager Aware of Water for 2060	2.376585*	2.353166*	0.023419	1.850058	0.526527	3.351472*	3.153819*	0.197653	2.672548*	0.678924
β Constant	0.296762	1.458368	-1.161606	-0.187802	0.484564	-3.912985	-1.817976	-2.095009	-3.635838	-0.277147
Model R2	0.778	0.629	0.524	0.69	0.671	0.665	0.505	0.615	0.545	0.699
Std. Error of the Estimate	3.465	3.596	1.808	3.141	1.335	4.255	4.155	1.627	3.809	1.277
***: p< 0.001; **: p < 0.01; *: p < 0.10										

Appendix A: Interview Guide

1. Five control questions about interviewee and water utility
2. Who do you feel is most responsible for water system management and innovations?
3. What types of skills, educational backgrounds, and/or certifications does your organization find most valuable?
4. What is the age (years) of the following components of the water system?
    - Pipelines (Water Supply Lines)
    - Pipelines (Plant to households)
    - Water treatment facilities
    - Water storage facilities
    - Storm water infrastructure
    - Waste water treatment system
    - Pumping Stations
    - Meter Systems
    - Valves (e.g. gate valves)
    - Other
5. What is the current state of quality of those components? (Ordinal scale)
6. What time frame does your utility plan to upgrade those components?
7. How vulnerable is your water system to the following factors? (Ordinal scale)
    - Decreased annual precipitation levels
    - Increased annual precipitation levels
    - Increased evaporation (from increased temperature)
    - Lack of departmental resources (e.g. limited employees for water management)
    - Increased water demand (from population growth)
    - Increased water demand (from economic growth)
    - State of current infrastructure
    - Excess of regulations
    - Lack of regulations
    - Other
8. Follow-up: Why did you rate ____ as not vulnerable or very vulnerable? Based on your rating of ____, how might this factor affect your organization's ability to adapt to changing environmental, social or economic conditions? What processes could be implemented to decrease this vulnerability? Describe how this process would occur? Why can your utility not take measures to decrease the vulnerability of ____ factor?
9. What could your utility do to improve the capabilities to respond to changes in water needs? Please describe specific capabilities that you have created and used. What factors increase or decrease the likelihood that such capabilities will lead to innovations? What barriers did your utility come across when attempting to improve capabilities?
10. How important are each of the following mechanisms for accurately tracking water supply and demand to future planning and decision-making? (Ordinal scale)
    - Efficient or automated valves and/or pumps
    - Installing/retrofitting water efficient devices in public (government) buildings (e.g. plumbing fixtures and appliances)
    - Retrofit/replacement of existing public (government) irrigation systems with more efficient irrigation systems.

- Offering retrofit/replacement incentives for more efficient agricultural irrigation systems in your community.
- Leak detection within the distribution system.
- Water audit and water conservation plans.
- Recycling and water reuse projects including gray water, condensate and wastewater effluent reuse systems.
- Meters with built in leak detection.
- Backflow prevention devices.
- Smart meter with water flow measurement and reporting capabilities.
- Contaminant sensors.
- Flood sensors.
- Automated meter reading capabilities.
- Other

11. Follow up: What were the most significant barriers to creating the mechanisms and how were they overcome? (e.g. key personnel, partnerships, capabilities).
12. Does your organization have mechanisms to draw upon in the event of a disaster (e.g. flooding, drought), such as risk contingency funds or municipal bonds? If so, describe the process of creating/using those mechanisms. If not, why has your organization not created such mechanisms?
13. How important are the following items to creating new innovations (e.g. new programs, technologies, infrastructure, institutional changes)? (Ordinal scale)
    - Compliance with regulations
    - Promoting environmental sustainability
    - Company reputation
    - Risk Management
    - Success of other water utilities' innovations/programs
    - Stakeholder pressure
    - Economic reasons (cost savings, organizational growth)
    - Future changes to the climate
    - Availability of funding (e.g. Water for 2060 Drought Grant Program from OWRB)
    - Adequate water supply for your community
    - Adequate water supply for your kid's generation
    - Spurring local economic growth
    - Other
14. Do you create strategic plans for your water utility? If yes, lets discuss the process that your utility uses to create strategic plans. When did you start creating these plans? What were the driving motivations for creating them? Who were the key personnel involved? What were the barriers to creating these plans? How were they overcome? How have these strategic plans been used? Have they been beneficial to the creation of innovations?
15. Has your utility sought external resources to help create innovations? If so, where do you seek these additional resources? Please describe those resources and how they were used in creating innovations. What were the motivations for pursuing these external resources? What barriers did you come across when pursing external resources?
16. How aware are you of the following state policies (e.g. Water for 2060 Act and OWRB Drought Grant Program)? Has your utility taken into account the Water for 2060 Act in regard to water planning and creating innovations? If yes, what actions results and please describe the process? If no, why not? Has your utility applied for the Water for 2060 Drought Grant Program from the OWRB? If no, is this something you would be interested in applying for?

17. How important are the following resources and capabilities to water system innovation? (Ordinal scale)
    - Strategic partnerships with governments (e.g. EPA, DEQ, OWRB)
    - Collaborations with organizations/stakeholders (e.g. NGOs, experts, universities)
    - Social capital (e.g. Personal Networks with utilities/professionals)
    - Openness to new/innovative ideas/programs/services
    - Long-term vision
    - Financial capital
    - Flexible Budgets
    - Internal organizational strategic planning/assessment
    - Internet Resources
    - Government documents (e.g. Oklahoma Water Resource Board)
    - Academic journals/studies
    - Pre-existing human capital (Knowledge, education)
    - Ongoing learning processes (Employee training/Educational seminars/on-the-job experiences)
    - Research and development (Internal)
    - Other
18. Follow up: Please describe why you rated ____ as important/not important.
19. Referring to the resources and capabilities, please indicate how each is used in the innovation process.
20. To what extent does your utility pursue knowledge creation and learning mechanisms for your employees? Has anyone in your utility participated in water/climate workshops/public meetings/training seminars/etc. put on by external organizations? If yes, please describe the experience. Was the information useful for creating innovations in your utility?
21. Please rate the following factors based on their significance to impede innovation within your utility: (Ordinal scale)
    - Fragmented organizational structures (overlapping responsibilities)
    - Stakeholder concerns
    - Regulatory actions
    - Alternative municipal priorities
    - Financial resources
    - Lack of expertise/knowledge
    - Risk averse organizational culture
    - Personal fear of failure (job security)
    - Organizational reputation
    - Other
22. Follow-up: why did you rate ____ as very/not significant?
23. Please describe the successful water related innovations that your utility has created in the past five years? Also in the current 12-month period? And planned for the next five years? Follow-up questions for each innovation included: how many innovations? Scale of each innovation? Frequency of each innovation? Year of implementation? What resources and capabilities were used in their creation? What barriers were encountered? How were the barriers overcome?
24. Are there any additional resources you would recommend for us to read to better understand programs/innovations/capabilities by your organization? (e.g. reports)