Customer Complaint Management and Smart Water Technology Adoption among Community Water Systems

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1. Abstract

High profile water quality events, including the Flint Lead in Water Crisis, have contributed to a decline in customer trust in water systems. Many Americans do not drink tap water because they perceive risks in the cleanliness of water. One way that community water systems (CWS) can build trust is through improved management of customer complaints. CWSs can store, track, visualize, and share customer complaints to improve service and improve the way that customers interact with information about water quality. Smart water technologies, including Advanced Metering Infrastructure (AMI), data portals, and personal device applications (apps) can be used to better communicate with customers and share information about water quality problems, and advanced data analytics can create new insight to manage sources of water quality problems. This research applies qualitative survey techniques to explore how CWSs perceive the use of customer complaint systems. Survey questions probe the existing tools that CWSs use to collect customer complaints, the adoption of smart technology by CWSs, and characteristics of customer complaints. Statistical techniques are used to assess differences in complaint reporting and management by water provider characteristics including size and use of smart technologies. Results indicate that medium, large, and very large CWSs have a greater desire for improved customer complaint management approaches, while smaller systems have fewer complaints on

average and prioritize other management needs above complaint management. Text analytics of survey responses yield insight on tools and capabilities that are needed to improve utility satisfaction with complaint management systems. This research develops new insight about CWS approaches to receive, store, and use customer complaints and provides a new perspective on one trust-building action of water providers.

2. Introduction

Water systems are complex sociotechnical networks, relying on the interaction of many actors and systems, including physical infrastructure, land-atmospheric processes, treatment processes, management decisions, and consumer behaviors (Berglund 2015). Water systems across the U.S. encounter many challenges in the treatment and delivery of water (ASCE, 2017), leading to a lack of confidence that consumers place in the reliability and safety of their drinking water. Aging infrastructure leads to pipe breaks and bursts, large volumes of lost water and revenue, and contamination of the water supply (ASCE, 2017). Underfunded water systems are limited in their ability to expand water networks to meet growing demands, renew and restore aging pipes, update computational systems with advanced technology, and improve levels of service (ASCE, 2017). A recent study estimated that 60 million Americans do not drink their water because they do not trust its safety (Rosinger et al., 2021). A high-profile water quality event can contribute to widespread dissatisfaction with water services: tap water confidence declined at an alarming rate from 2017 to 2018, after the Flint Lead in Water Crisis, in which toxic levels of lead were discovered at multiple households connected to a water distribution system in Michigan (Rosinger et al., 2021). The relationship between water customers and water providers impacts water resources management, and fostering communication with customers can improve customer confidence in water utilities (Yang and Faust, 2019; Junker and Carpenter, 2021; Weisner et al.,

2020). Studies indicate public trust in the quality of water provided by community water systems (CWSs) is dynamic and shifts in response to news media coverage of water issues (Yang and Faust, 2019; Weisner et al., 2020). Customer trust also changes with socioeconomic factors such as nationality, education level, and household income (Pierce and Gonzales, 2017). Higher customer satisfaction may be facilitated through improvements in (1) the mechanisms that utilities use to receive, store, and use customers report complaints around water discoloration, odor, and taste and (2) the approach that water utilities use to communicate water quality issues (Weisner et al., 2020).

Consumer complaints, which tend to focus on taste, odor, and discoloration of tap water, can provide an important supplemental source of information about problems in the water system and can be analyzed to identify episodic water quality problems or water contamination events (Whelton et al. 2006; Drake and Zechman 2012; Gallagher and Dietrich, 2014; Dietrich et al., 2014). Text codification can be used to automatically analyze complaints (Dietrich et al., 2014), and research has demonstrated that a high frequency of complaints and consistent descriptors can indicate the occurrence of water quality events (Gallagher and Dietrich, 2014). While conventionally, customer complaints are handled by phone operators at water utilities (Tian et al., 2022), new mechanisms to more efficiently collect and use complaints are emerging through smart city technologies. Digital technologies that are enabled by Information Communication Technology (ICT) can collect sensed data and connect infrastructure, communities, and infrastructure managers (Berglund et al., 2020). Smart technologies, such as social media, text alerts and data dashboards, can facilitate data collection and enhance information transfer between water service providers and consumers (Grupper et al., 2021). Information streams from smart technologies and social media enhance the ability to capture and sort the content of complaints, making additional analytics possible. For example, text mining was applied to Tweets expressing

issues with water quality (Dewinta and Irawan, 2021), and natural language processing was applied to water service complaints that were submitted through an online system (Tian et al., 2022). Complaints were clustered based on the type of problem identified, and analysis identified recurring issues for utilities; specifically, 27.8% of complaints pertain to pipe leaks (Dewinta and Irawan, 2021). An open-source software platform was developed to use customer complaint clustering for detecting water quality events (Mounce et el., 2012).

Smart technologies can also improve the communication of CWSs with customers. Streaming data about customer behavior and system performance can be communicated through online portals, apps, and websites to provide real-time accurate data to water customers. Advanced Meter Infrastructure (AMI) places smart meters at customer accounts to report hourly and sub-hourly demands. Utilities can report AMI data to consumers to provide sub-hourly insights about water consumption (Beal and Flynn, 2014). Data visualization platforms have been developed to show household consumption trends to encourage conservation (Novak et al., 2018). Utilities can also use social media can expand the reach of utility communications (Heath, 2020), and research has demonstrated how short message service (SMS) alert systems can be used to quickly contact customers about a water quality incident and improve public health outcomes (Strickling et al., 2020). Smart technologies can also provide advanced methods to visualize current and reported water quality issues. A digital twin is a computational replica of a real-world pipe system and the community of users. A digital twin mimics the physical system's behavior and can be used to quickly assess and forecast hydraulic performance by integrating changes in consumer demands (Pesantez et al., 2022). Digital twins can be used to generate maps of contaminated pipes and vulnerable populations to facilitate CWS communication about water quality issues with customers.

This study explored CWS perspectives around using smart technology and communicating with consumers through receiving, storing, and using complaints. Surveys can be an effective approach for capturing emerging industry trends that impact water service. Surveys and interviews have been used in previously conducted research to explore, for example, the impacts of the COVID-19 pandemic on water utilities (Spearing et al., 2020; Smull et al., 2021; Berglund et al., 2022); utility perspectives on climate and sustainability (Landis, 2015; Dow et al., 2007); water utility finances (Boyer et al., 2012); and communication practices (Liu and Mukheibir, 2018; Annesi et al., 2021; Evans and Carpenter, 2019; Dziedzic and Karney, 2016). Related research conducted a survey of 240 water providers to ascertain how utilities track consumer feedback, with a specific focus on increasing the effectiveness of consumer confidence reports (CCRs) (Evans and Carpenter, 2019). Results indicated that 81% of utilities surveyed use at least one method to track customer understanding of consumer confidence reports, and larger utilities are more likely to use additional approaches (Evans and Carpenter, 2019). Other related research explored the adoption of smart technologies and digitization within the water industry. Berglund et al. (2022) conducted semi structured interviews with 28 US water utilities and found that the adoption of smart technologies, especially those which reduced the need for in-person correspondence between utilities and customers, greatly increased during the COVID-19 pandemic. Beal and Flynn (2014) conducted a longitudinal study from 2013 to 2014 of more than 26 Australian and New Zealand water utilities tracking digitization of utility practices over time and observed that the number of utilities pursuing smart water metering doubled during that time.

This research investigated the approaches that CWSs employ to receive, store, and use customer complaints through a survey instrument. More than 500 respondents representing U.S. CWSs participated in the survey. Data were analyzed to evaluate the approaches that CWSs use to

communicate with customers, CWS adoption of smart technology, and CWS use of customer complaint data for operational insights. Statistical techniques are applied to assess the types of complaint reporting and management systems that are used by CWSs of varying sizes and by CWSs with different smart technology capabilities. Results demonstrate how the size of utilities relates to the desire for improved customer complaint management approaches and highlight smaller CWSs receive fewer complaints on average and prioritize other management needs above complaint management. Text analytics of survey responses yield insight on tools and capabilities that are needed to improve utility satisfaction with complaint management systems. This research develops new information about approaches to receive, store, and use customer complaints and develops an important perspective on trust-building actions of water providers.

3. Methods

3.1 Survey Design and Distribution

A database of contact information for CWSs was developed using an internet scraper of publicly available, online records of organizations that manage CWSs in the U.S. All survey participants consented to sharing information about their water service operations, and the instrument was approved by an NC State University Institutional Review Board. The survey was 46 questions in length and took approximately 15 minutes to complete. Respondents who indicated their consent and self-identified as a part of an organization that provides water services were subsequently shown the full survey. No incentives were offered. Responses were collected across the U.S. over a period of three weeks in September 2021.

The online survey was distributed via Qualtrics surveying software. Qualtrics conducted a soft-launch survey pilot to evaluate the survey instrument and employed quality measures, including flagging responses submitted in less than a third of the average response time, incoherent

responses, and inconsistent responses. The full survey is presented in Appendix A. In total, 504 quality-controlled responses were collected.

4. Results

4.1 Respondent Characteristics

Survey results about respondent characteristics are tabulated and presented graphically. Survey respondents varied widely in location, size, urbanization, and other operational details. Respondents self-described their service areas, with the following distribution of respondents among categories: 51% rural, 13% suburban, 32% small city or city outskirts, and 3% large cities. Most of the water providers (62%) reported groundwater as their region's primary water source, while 31% reported surface water sources, and another 7% indicated other water sources, such as provided by another supplier, spring water, or cisterns. Eighty percent of the water providers surveyed are publicly owned, 12% were reported as private companies, and the remaining responses indicated other ownership cases, such as quasi-public, quasi-governmental, or a homeowner’s association. There were at least 30 responses received from each US Census Bureau region (West, Midwest, Northeast, and South), with most responses (196) from the South.

Table 1 summarizes the size distribution of the CWSs that responded to the survey, based on sizes provided by the U.S. EPA (2021). In summary, 26.5% of responses were provided by very small CWSs, defined as servicing fewer than 500 people. Most respondents (32.3%) represented small CWSs, which serve populations from 501 to 3,300 households. Another 17% of responses represented medium CWSs servicing 3,301 to 10,000 households, and 17.6% of respondents represented large CWSs with up to 100,000 people. The remaining 4% of responses were provided by very large water systems with a population of more than 100,000, including three respondents

serving more than one million people. In total, this survey collected responses from water systems that service approximately 5.1% of the US population (US Census, 2020). The total sample (N=504) is a statistically representative sample size for the total number of CWSs in the U.S. (US EPA, 2021). Individual categories, including very small, small, medium, large, and very large, do not report statistically representative samples. Very small CWSs, which serve fewer than 500 people (Table 1), are represented well in this survey, however, compared to a recent utility survey that was conducted that included only two very small CWSs and 34 small CWSs (Evans and Carpenter, 2019).

Table 1. Size of CWSs that responded to the survey. [a] U.S. population is 329 million (US Census, 2020). Some estimates of CWS populations are based on data collected through a previous census. [b] Data from U.S. EPA, 2021.

Respondent Size	Amount Served	Number of Responses *(% of Respondents)*	Number of CWSs in the US [b]	Total Population Represented by Respondents	% US population served
Very Small	< 500	134 *(26.5%)*	26,963	35,391	0.01%
Small	501-3,300	178 *(35.3%)*	13,334	258,376	0.08%
Medium	3,301-10,000	86 *(17.0%)*	5,022	514,099	0.16%
Large	10,001-100,000	89 *(17.6%)*	3,975	2,788,882	0.85%
Very Large	>100,000	18 *(3.6%)*	446	13,047,691	3.97%
	Total	504 *(100%)*	49,740	16,644,439	5.06%[a]

4.2 Adoption of Smart Technology

Respondents replied to questions about the adoption and implementation of smart technology (Table 2). Overall, 60% of respondents have a social media presence. The adoption of AMI and smart meters was less common among very small providers (28.8%) and increased with size, and 78.9% of very large CWSs have deployed smart meters. In fact, several technologies have been adopted at large CWSs and more sparingly among smaller systems. For example, hydraulic models are implemented by 89.5% of very large CWSs and 62.5% of large CWSs, but under 50% for other sizes. Similarly, SMS alerts and pressure sensors are common at larger utilities and used rarely at small ones (Table 2). Less than 40% of respondents of any CWS size employ data dashboards that can visualize household consumption trends or allow consumers to regularly view their usage online. Artificial intelligence (AI), machine learning (ML), and digital twin approaches are not used widely across any group of respondents.

The survey explored barriers to the adoption of smart technologies. Participating CWSs reported that barriers include finances (38% across all respondents), not enough personnel (23%), lack of staff training (22%), and that smart technologies add no value for the CWS (11%). Another 6% of respondents answered “other” and provided text response that described other barriers. Several respondents cited lack of customer participation to implement new services, including a description of a “large senior population [with] low adoption of paperless billing and electronic form submission”. Another theme of the text responses was trepidation about new techniques, such as responses stating, “concerns about security”, “personnel resistant to change”, and “poorly established innovation goals”. Finally, some respondents discussed difficulties managing rural and remote water systems that impede smart technology integration such as “our service area is spread out”, “terrain and geographic issues” and “limited internet and phone”. The survey also asked

about CWS budgets for smart technology, which is important because finances was the most frequently reported barrier to the adoption of smart technologies. Budgets increase on average with CWS size, and 27.8% of very large CWSs indicated that they budget at least $500,000 USD for smart technologies.

Table 2. Smart technologies used by CWS size

Respondent Size	# of Responses	Percent of respondents with smart technology							
		Social Media	AMI	Hydraulic Models	Pressure Sensors	SMS Alert	AI/ ML	Data Dash-board	Digital Twin
Very Small	134	41.67	28.79	15.15	26.52	17.42	0.76	12.88	0.00
Small	178	57.78	46.11	18.89	27.22	20.56	2.22	21.67	0.56
Medium	86	69.77	67.44	48.84	30.23	27.91	1.16	26.74	1.16
Large	89	77.27	77.27	62.50	47.73	37.50	3.41	35.23	0.00
Very Large	18	94.74	78.95	89.47	78.95	63.16	15.79	36.84	0.00
Total	504	60.28	51.98	33.33	33.13	25.59	2.38	23.21	0.38

4.3 CWS Capabilities to Receive Complaints

The ability of a CWS to efficiently handle customer complaints is likely influenced by a broad range of factors, including population served, the volume of complaints and the format in which these are received. Out of all 504 respondents, 363 indicated that the most common way they receive complaints is by phone call, accounting for more than 75% of responses in each size category (Figure 1a). Survey results also indicate a wide variation in number of complaints received per week by CWS size (Figure 1). Most respondents from very small (90.9%), small (91.1%), medium (80.2%), and even large (62.5%) CWSs receive less than five complaints per

week (Figure 1). The volume of complaints generally increases by size, and 42.1% of the very large CWSs that responded receive 6 to 25 complaints per week, with 10.5% receiving more than 50. The very large response group includes 19 CWSs with more than 100,000 people, including three respondents serving than more than a million people, which accounts for the wide range in number of complaints received among that group (Figure 1b). There was also a wide variation in responses to the survey question "Approximately how many employees at your organization manage communications with customers about their water?" Very small (93%), small (89%) and medium (71%) respondents have less than five employees working with customer communications. Large and very large CWSs report that more employees work with customer communications, and 16% of very large respondents have more than 20 employees working with customer communications.

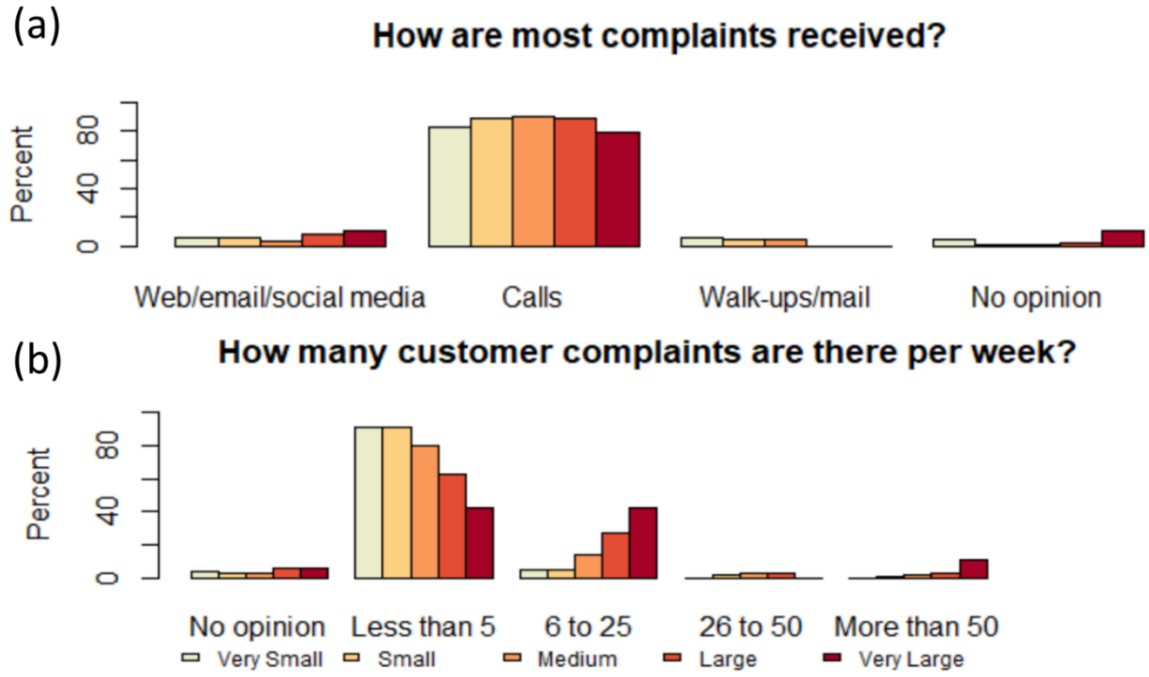

Figure 1. (a) Percent of responses by size to "How are most complaints from customers received?" (b) Percent of responses by size to "How many customer complaints are there per week?"

Participants were asked about the level of challenges associated with customer communication. Participants responded to the question “How challenging is it to communicate with customers?” with answers of “Not at all”, “Somewhat”, or “Very”. The average for each group is shown as an orange line in Figure 2, and the level of challenge increases marginally with CWS size. These responses are evaluated in the context of the level of adoption of social media (shown as bars in Figure 2). Social media use increases steadily with CWS size, from 42% among very small CWSs to 95% among very large CWSs. Many very large CWSs have adopted social media, and they are affected by more challenging communication with customers, compared with their smaller counterparts. Cramer’s V is a measure of correlation between two nominal variables. Cramer’s V is used in social science research on categorical data and can range from 0 to 1. A value less than 0.10 indicates a weak association; 0.10 to 0.25 represents a moderate relationship; and greater than 0.25 is a strong relationship (Cramér, 1946). There is no correlation between social media and challenges with customer communication (Cramer’s V = 0.0), indicating that these responses are independent for individual CWSs. The adoption of social media is moderately correlated with CWS size (Cramer’s V = 0.20), and the challenges with customer communication is not correlated with CWS size (Cramer’s V = 0).

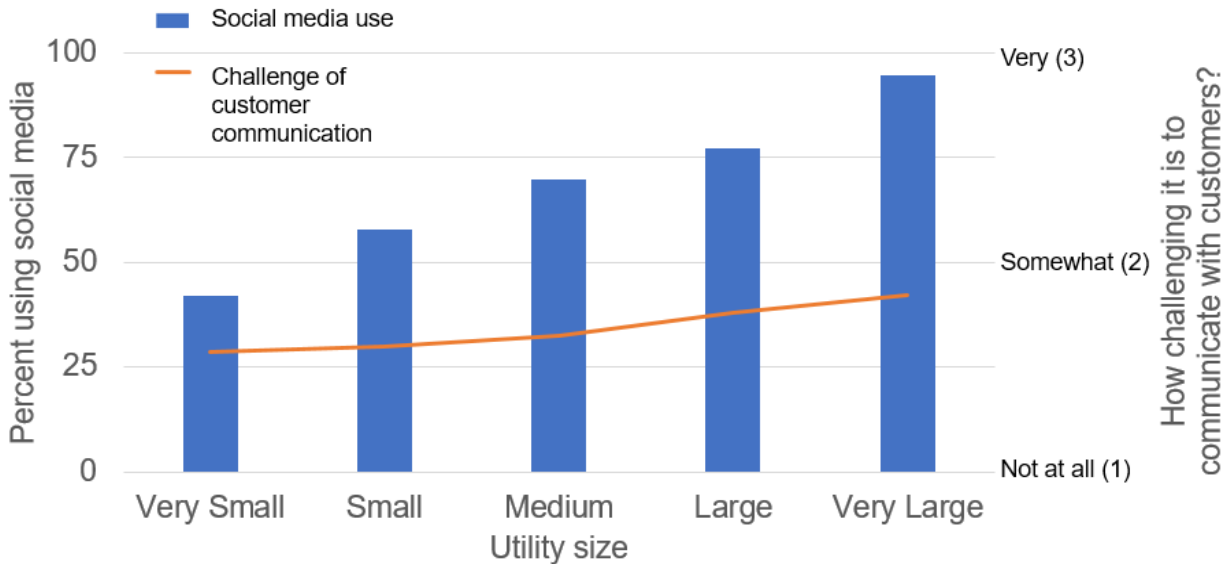

Figure 2. Comparing percent of respondents using social media per size (bar plots) and line plot of perceived level of challenge in communicating with customers by size

4.4 CWS Capabilities to Store and Organize Complaints

Responses to survey questions about approaches for storing and organizing customer complaints are explored by CWS size. Figure 3 shows responses by size to the survey question "How are customer complaint records being stored?". Analog records are less common as CWS size increases. Most large (59.1%) and very large (84.2%) CWSs store records of customer complaints digitally. Small (49.4%) and very small (33.3%) systems report mainly storing records on paper. Among very small providers, 21.2% do not store records of customer complaints at all. Figure 4 compares the respondent characteristic of storing records mostly in digital form with a survey question about satisfaction with current methods of storing data. Level of satisfaction with current storage method decreases slightly with CWS size, while the number of CWSs that store records digitally increases sharply. Responses between questions about storage type and satisfaction with storage methods are moderately correlated (Cramer's V = 0.12).

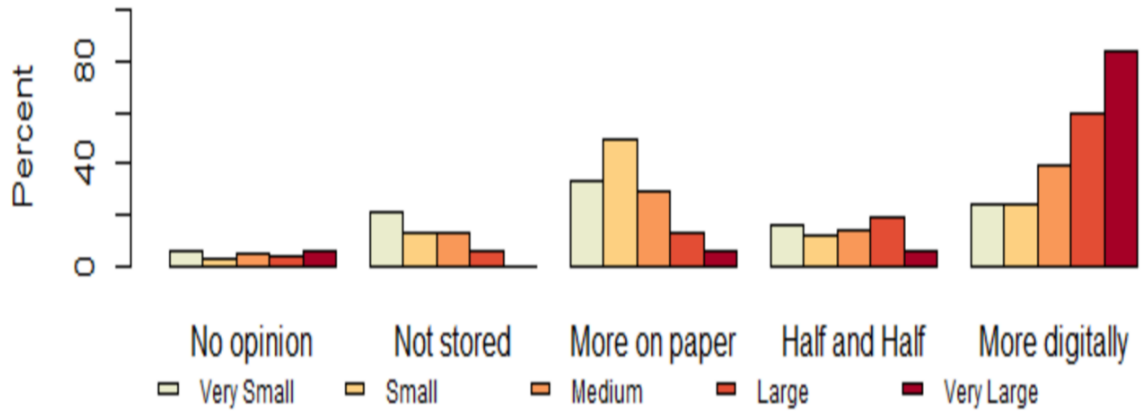

Figure 3. Respondent responses to question, "How are customer complaint records being stored?"

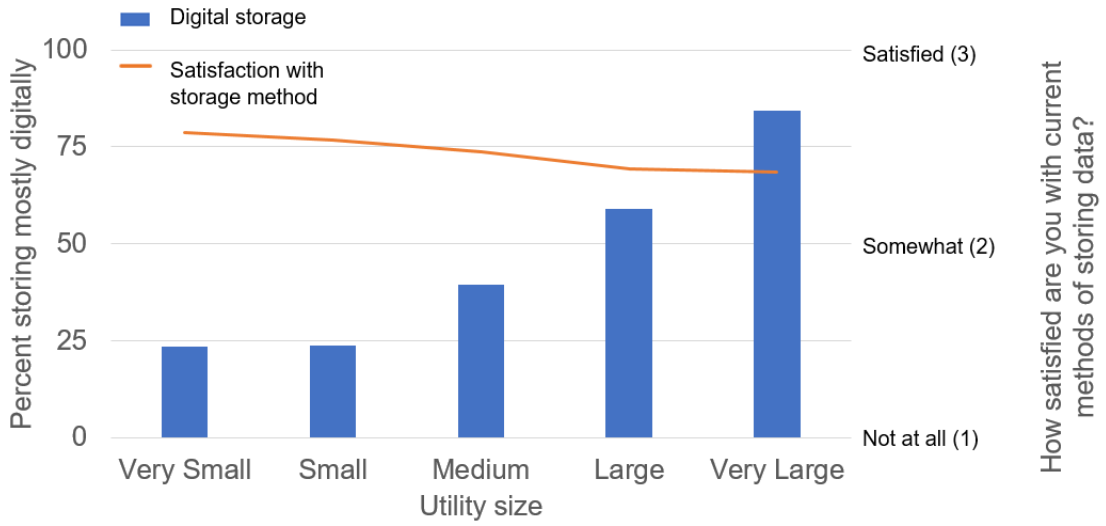

Figure 4. Percent of respondents who store records mostly digitally by size (bar plots) and line plot of satisfaction with current method of data storage decreasing by size

When asked about current methods of organizing and storing customer complaints the percentage of respondents who are satisfied is 59%, somewhat satisfied is 33%, and not at all satisfied is 8% across all CWS sizes (Figure 5). Respondents who indicated that they were somewhat satisfied or not at all satisfied were asked a follow-up question, "Please elaborate on what could improve your satisfaction." Responses to these questions were coded based on a set of themes that were identified across responses (Figure 5). Figure 5 also lists representative responses

that characterize each theme. The primary themes of the text responses include adding data analysis or more capabilities (Theme S1, cited by 34% of respondents overall); storage size/logging issues (Theme S2, 22%); changing paper systems/not automated (Theme S3, 26%); human resources; (Theme S4, 11%) and other priorities besides storage (Theme S5, 7%). The distribution of responses across CWS sizes is shown in Table 3. Theme S2 was the most common theme for very small respondents (30%), followed closely by Theme S3, improving paper systems/automation (25%), which was also the main area of improvement described by small (36%) and medium (37%) CWSs. Large respondents were most interested in identifying ways to increase satisfaction in their system's data analytics or have more capabilities (Theme S1 = 50% for large CWSs). 100% of very large CWSs identified topics from Theme S1 to improve satisfaction with organizing and storing customer complaints.

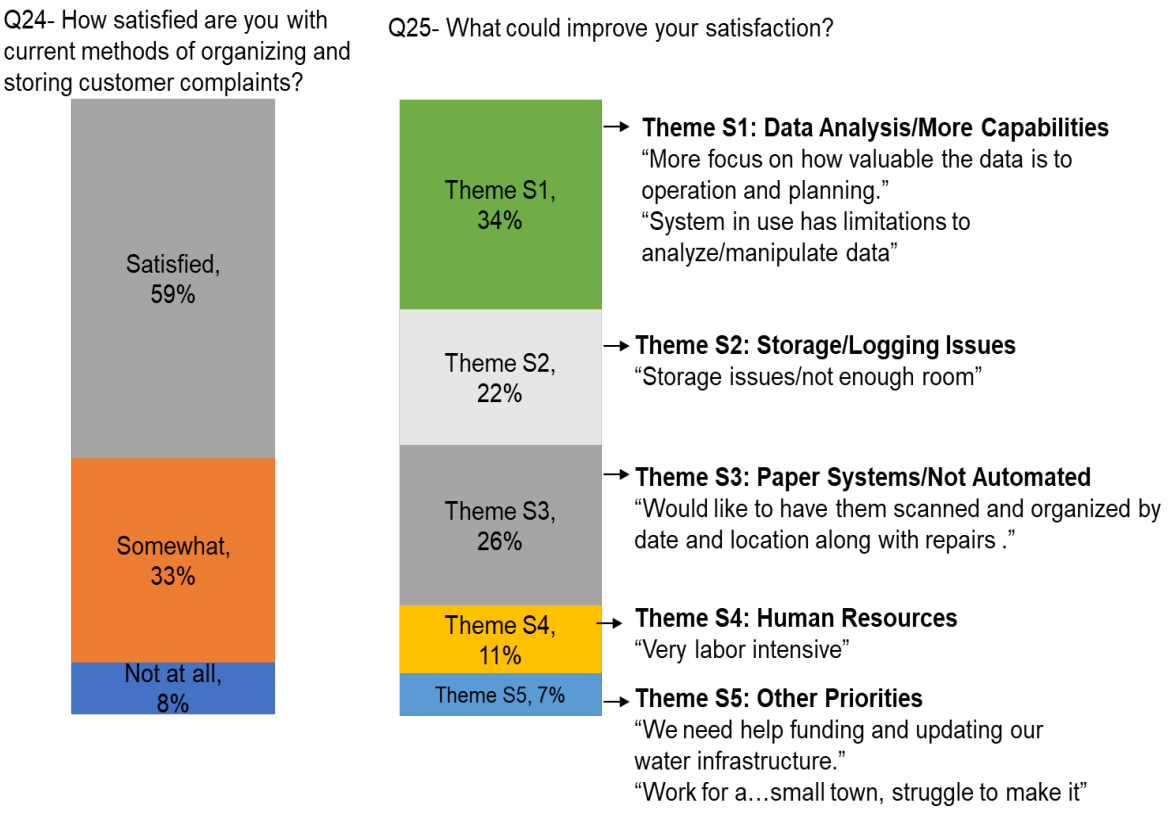

Figure 5. Respondents' satisfaction with customer complaint storage (Q24, 504 responses) is shown on the left panel. Themes established from text analysis of what could improve satisfaction with customer complaint storage (Q35, 107 responses) are shown on the right panel.

Table 3. Themes of improving satisfaction with storage by CWS size

Respondent Size	Responses to Q24	Satisfied	Somewhat satisfied	Not at all satisfied	Text responses	Theme S1	Theme S2	Theme S3	Theme S4	Theme S5
Very Small	131	62%	34%	5%	20	15%	30%	25%	15%	15%
Small	180	62%	30%	8%	33	27%	24%	36%	6%	6%
Medium	86	56%	36%	8%	19	21%	21%	37%	16%	5%
Large	88	51%	36%	13%	30	50%	20%	13%	13%	3%
Very Large	19	53%	32%	16%	19	100%	0	0	0	0
Total	504	59%	33%	8%	107	34%	22%	26%	11%	7%

4.5 CWS Capabilities to Use Complaint Data

The survey also explored how CWSs use complaint data to track system wide trends. Approximately half of very large utilities track system wide trends from complaint data (52.6%). Otherwise, at least 30% of very small, small, medium, and large water providers are using data to track system wide trends, but more often indicated not doing so (Figure 6). Table 4 presents a contingency table that displays the frequency distribution of the approaches that CWSs use to store complaint data and their efforts to track system wide trends. Forty-two percent of CWSs that mostly use digital storage methods of complaint data also report using that data to track system wide trends, while only 34.4% of those with paper storage and 6.7% of those not storing complaint records reporting tracking trends (Table 4).

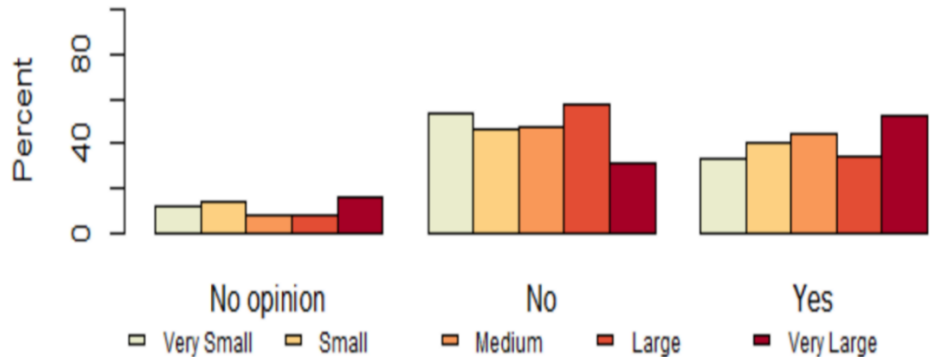

Figure 6. Percent of responses by size to "Is complaint data used to track system wide trends?"

Table 4. Contingency table of CWS approach for storing complaint data and efforts to track system wide trends

	Not stored	More on paper	Half and half	More digitally	No opinion
Yes, tracks trends	6.7%	34.4%	14.9%	42.1%	2.1%
No	18.7%	33.7%	11.9%	32.9%	2.8%
No opinion	12.3%	31.6%	22.8%	19.3%	14.0%

Across all respondents, 64% reported that their customer complaint data is being utilized to its full potential (Figure 7). The survey also asked an open-ended question about current ways the data is used, if the respondent indicated it is fully utilized. Another open-ended question asked respondents what additional potential uses of the data are, if they indicated that the data is not fully utilized. Responses from these questions are analyzed together. Examples from common themes about complaint data use applications are featured in Figure 7, and a breakdown by number of responses within each theme in Table 5, including Theme U1: to direct funds or identify system upgrades; Theme U2: for education and communication purposes; Theme U3: to track trends and solve problems; and Theme U4: too few complaints overall to make use of them. Citing too few complaints (U4) was far more common among very small CWSs (67%), and the frequency of Theme U4 decreases with size (Table 5). Many small CWSs also describe too few complaints to

make use of them (35%), but more often described uses of the data to find and solve problems or keep track of system trends (Theme U3, 37%). Most medium (55%), large (55%) and very large (50%) CWSs responded with Theme U3 (Table 5).

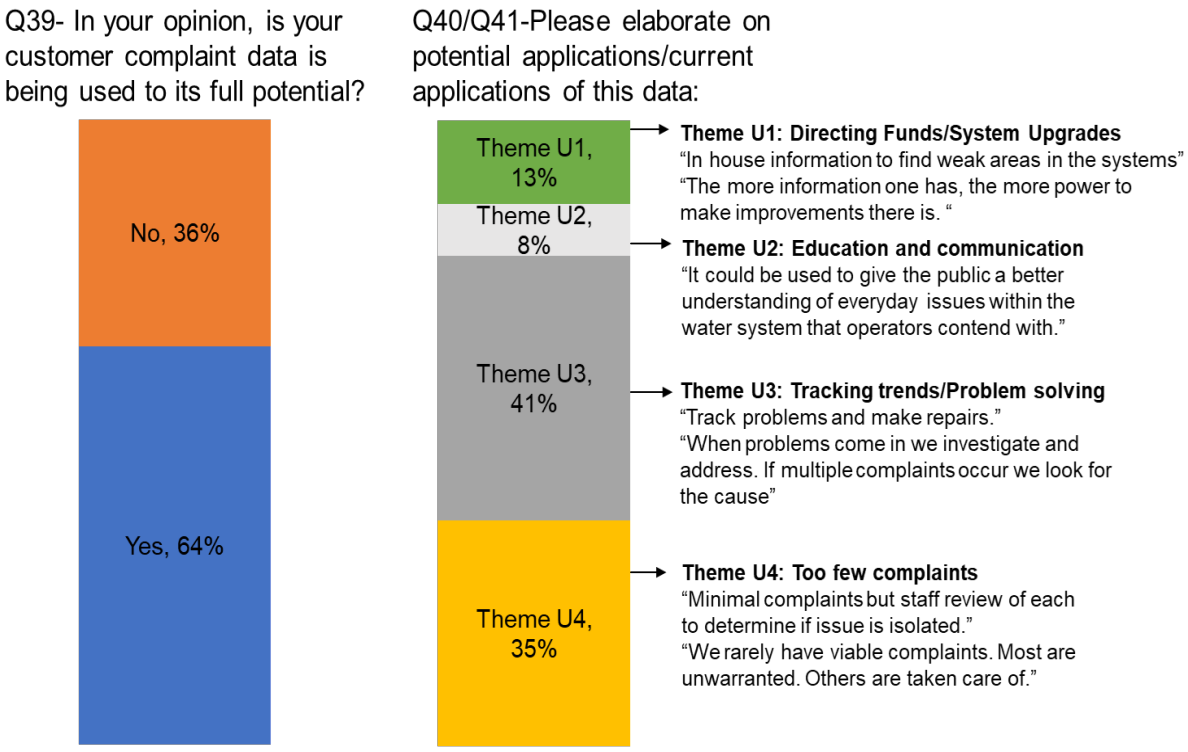

Figure 7. Percent of respondents who feel customer complaint data is fully utilized (left) and breakdown of the themes established from text analysis of uses of this data (right)

Table 5. Themes of customer complaint data uses by CWS size

Respondent Size	Responses to Q39	Yes	No	Text responses	Theme U1	Theme U2	Theme U3	Theme U4
Very Small	81	94%	6%	57	7%	4%	23%	67%
Small	118	83%	17%	62	11%	11%	37%	35%
Medium	51	75%	25%	38	16%	11%	55%	13%
Large	47	51%	49%	38	21%	8%	55%	16%
Very Large	15	33%	67%	12	8%	8%	50%	8%
Total	312	77%	23%	207	13%	8%	41%	35%

4.6 Correlation between respondent characteristics and areas of interest

The relationships among respondent characteristics with methods of receiving, storing, and using customer complaints are assessed using Cramer's V statistic. Figure 8 shows Cramer's V correlation results between CWS characteristics and attributes of how CWSs receive, storage, and use customer complaints. CWS characteristics include U.S. region, ownership type, primary water source, frequency of customer communication (commfreq), number of employees managing customer communications (commemployees), amount of smart technology budget (smartbudget), CWS size, and urbanization (urbanize). Additionally, types of smart technology in use are included, such as social media, SMS alerts, data visualization platforms (dataviz), pressure sensors (psensors), hydraulic models, ML/AI methods and smart meters/AMI. Attributes assessed include responses to the questions "How do you store records of customer complaints about water?" (Y1); "Is your organization concerned about storing digital records of customer complaint data?" (Y2); "How satisfied are you with the current method of organizing and storing customer water

complaints?" (Y3); "Is customer complaint data used to track system wide trends in water quality?" (Y4) and "How challenging is it to communicate with customers?" (Y5).

Some CWS characteristics are correlated; for example, the size of the CWS and the reported level of urbanization (with answer choices ranging from rural to large city) are strongly correlated (Cramer's V = 0.42). Many smart technology implementations are also correlated; for example, CWSs that had pressure sensors are also likely to have hydraulic modelling (Cramer's V = 0.46).

As seen in Figure 8, most characteristics are weakly associated with the attributes of interest (Cramer's V < 0.10). Moderate correlation is observed between Y1 (storage method) and the number of complaints per week, CWS size, urbanization, amount of smart technology budget, U.S. region, the number of employees in communications, and having several smart technology types including social media, SMS alerts, data visualization platforms, pressure sensors and AMI (Figure 8). Y1 is strongly correlated with hydraulic modeling technology. The amount of smart technology budget, implementing data visualization, and hydraulic models is moderately correlated with Y2 (concern with digital storage) (Figure 8). Y3 (satisfaction with storing and organizing complaints) was not correlated with respondent characteristics (Figure 8). Y4 (tracking trends) is moderately correlated with responses to water source, number of employees in communications, amount of smart technology budget, CWS size, urbanization, data visualization, hydraulic models, and number of complaints per week (Figure 8). Challenges with communication had no moderate or strong correlations with the CWS characteristics tested.

Overall, there are moderate correlations between the characteristics of a CWS including their level of smart technology integration and concerns with storage method (Y2), how data is stored (Y3), system-wide trend tracking (Y4), and communication challenges (Y5) (Figure 8).

Responses about satisfaction with the way data is stored (Y1) were highly correlated with implementation of hydraulic models.

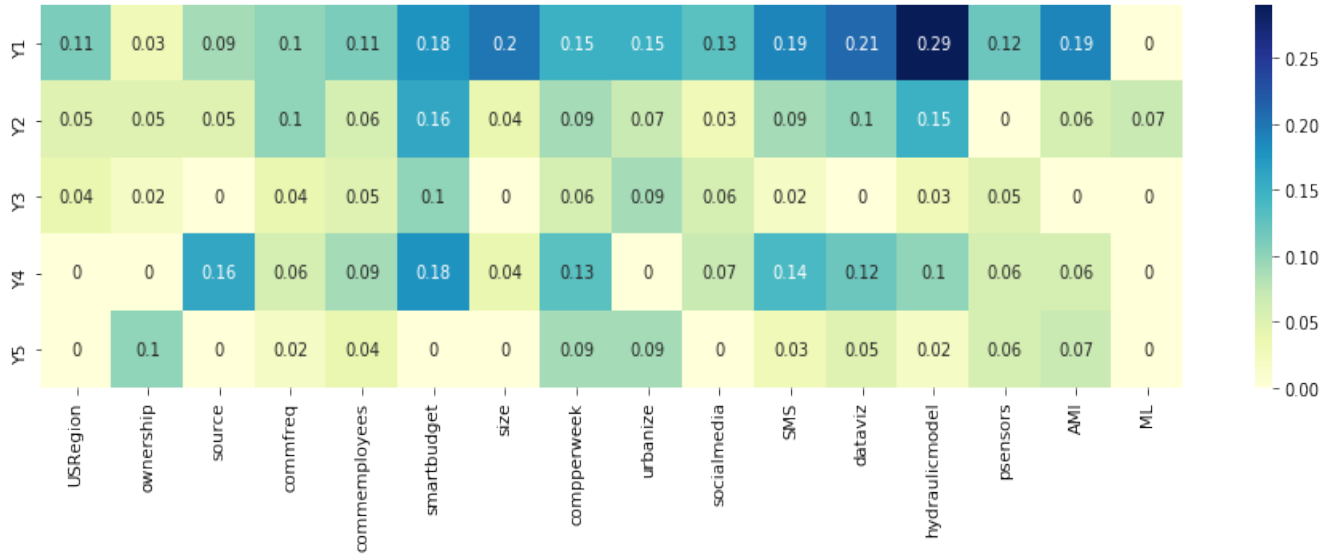

Figure 8. Cramer's V correlation shown for respondent characteristics and attributes of customer complaint storage. Darker color indicates stronger correlations.

5. Discussion

This study advances an understanding of customer complaint management approaches, building upon knowledge developed in previous surveys which capture utility perspectives on industry trends such as improving water quality communications (Evans and Carpenter, 2019), operational changes during COVID-19 (Spearing et al., 2020; Smull et al., 2021; Berglund et al., 2022), and transitioning to digital technologies (Beal and Flynn, 2014). Across the 504 survey responses analyzed in this research, 26.5% came from very small CWSs serving less than 500 people, capturing a different subset than other recent surveys that explore customer interactions which had respondents predominately from large utilities (Evans and Carpenter, 2019). Results develop important insights about differences in complaint management and operational priorities for CWSs of all sizes.

Literature indicates that smart technologies can support efforts in communication between water providers and the public, including text alerts to disseminate a water quality incident (Strickling et al., 2020) or social media to create a two-way dialogue between utilities and customers (Grupper et al., 2021). Interviews with 28 U.S. water utilities indicated that smart technology adoption is on the rise and increased during the COVID-19 pandemic (Berglund et al., 2022), and a long-term study of 26 water utilities in Australia saw a doubling in the uptake of smart meters (Beal and Flynn, 2014). This survey expands these findings with new information about how CWSs are using smart technologies, barriers to implementing smart technologies, and the effects of these interventions on the ability to address customer complaints.

Previous studies have also explored how data from customer complaints can be used for system insights such as detecting water quality episodes (Gallagher and Dietrich, 2014) and recurrent problems like pipe leaks (Dewinta and Irawan, 2021). This study identifies characteristics that are important in how water providers approach receiving, storing, and using customer complaints. Additionally, text analysis reveals a wide range of perspectives on how to improve satisfaction with customer complaint storage methods and ways that water providers desire to use the complaint data they collect.

5.1 Disparities in smart technology adoption

Smart technologies including internet-enabled water meters, social media, hydraulic models, real-time pressure sensors and data visualization platforms help streamline CWS operations, improve communication with customers, and offer structure for storing and processing customer complaint data (Berglund et al., 2020; Heath, 2020; Novak et al., 2018; Cominola et al., 2015). Most CWSs, regardless of size, reported that it would be at least somewhat challenging to incorporate new smart technologies in their service area, with primary barriers being finances and

personnel issues. However, results show differences in smart technology uptake by CWS size, and, specifically, smaller CWSs may have unequal access to tools that can improve infrastructure monitoring, operation, and management such as hydraulic models and real-time pressure sensors. Additionally, only 15.8% of very large CWSs and less than 5% of all smaller sizes reported using artificial intelligence or machine learning analytics, indicating that these approaches are still cutting-edge and lack widespread uptake at present (Table 2). Similarly, only two CWSs indicated using digital twins.

Several respondents (6%) wrote open responses about barriers to smart technology adoption, providing new understanding about the range of challenges CWSs may face. CWSs are faced with a lack of customer participation, trepidation about new techniques, and challenges managing rural and remote water systems. These insights give important context for the bounds of digital transition in water systems, which relies on adequate funding, privacy and security measures, staff training, and the performance of interconnected public services such as internet and phone.

5.2 Priorities of small CWSs

The survey assessed methods that CWSs use to receive, store, and use customer complaints. Most respondents receive complaints by phone call, but the number of complaints received varies greatly by size. Most very small CWSs receive less than five complaints per week, and when asked about ways to better utilize information from complaints, 67% of them responded that there were too few complaints to make use of the data (Table 5). This alludes to a difference in priorities, where large CWSs can focus on customer complaint management as a priority, while smaller providers are more pressed by issues of funding, crumbling infrastructure, and understaffing. Overall, respondents indicate that given adequate maintenance and customer service

staff, most CWSs receive a small and manageable volume of complaints weekly, with 82.6% of respondents receiving less than five complaints per week and only 3.8% reporting that customer communications are very challenging. As CWSs increase in size, growing numbers of complaints begets additional tools or smart technologies that can support response to and resolution of these issues.

5.3 General satisfaction about storage methods with room for improvement

Methods of complaint storage can aid CWSs in responding to recurring complaints and using clusters of complaints to identify system-wide issues. For example, Gallagher and Dietrich (2014) implemented statistical analyses on the content of customer complaints from six utilities and found that incidences where there was both a high frequency of complaints and consistent descriptors in the data coincided with real episodic water quality problems. Among very small providers, 21.2% do not store records of customer complaints at all. With inaccessible or non-existent records, additional analyses of complaints that can yield operational insights are not possible. Yet, among very small and small CWSs where few complaints are received and satisfaction with storage methods is high, sparse records likely will yield few additional insights. To elaborate, 91.6% (very small) and 91.1% (small) receive less than five complaints per week. As presented in Table 3, 62% of respondents from both small and very small groups are satisfied with their procedures for storing and organizing complaints. These indicate that smaller CWSs tend to have a very limited pool of complaints with which it would be difficult to conduct any meaningful trend tracking or additional analyses. Approximately half of the medium, large, and very large CWSs indicated satisfaction with storage methods, indicating room to explore new technologies and methods to improve satisfaction among these groups. Text responses about improving satisfaction with storage methods included themes such as adding more capabilities,

reducing storage size restrictions, changing from paper to digital systems, improving human resources or staff issues, and simply having other priorities besides data storage methods. All the very large CWSs and 50% of the large CWSs suggested adding data analysis or more capabilities to their storage software, including text responses like needing "to consolidate all complaints", "present data visually", "a better electronic interface to enter complaints for location and time of event" and "some form of data base that can interface with geographic data regarding complaints". On the other hand, 15% of very small CWSs described other priorities they need to be satisfied besides storage, such as "help funding and updating … water infrastructure".

Implementing social media is not directly related to better customer communication, and digital records do not lead to more satisfaction with storage methods. However, there is evidence that smart technologies benefit customer complaint management approaches. A propensity to track systemwide trends increases among CWSs that use digital records of complaint data. This supports the concept that digitalization and the integration of smart technologies is useful to water providers in their efforts to make system wide improvements, especially for larger CWSs.

5.4 Transforming customer complaint data into actionable information

A majority, or 67% of respondents, indicated their customer complaint data is being used to its full potential. A set of open-ended questions further explored current and potential applications of these data. Some water providers indicated that data is fully utilized simply because there are so few complaints, and they can effectively solve customer issues case-by-case as soon as they arise (Theme U4). Citing too few complaints accounted for 67% of very small CWS responses. This theme, however, decreases with CWS size. Other responses described that complaint information is used to guide decisions about capital improvements and to identify areas where infrastructure repairs are needed (Theme U1, 13% overall) or educate the public about water

system operations (Theme U2, 8% overall). Approximately half of medium (55%), large (55%) and very large (50%) CWSs responded that another use for customer complaint data is tracking trends and identifying problems. Respondents expressed a need for methods or algorithms to improve understanding of system wide water quality, flag customers with payment issues, and identify root causes of customer issues. These responses introduce fertile areas for future research and potential product development.

5.5 Correlations among respondent characteristics and customer complaint management

The relationship between respondents' characteristics and customer complaint management are assessed. Size, water source, urbanization, and number of employees dedicated to customer communications are all moderately correlated with aspects of complaint management. Smart technology budget and smart technology adoption are moderately correlated with methods for storing complaint records, concern with storing digital records, satisfaction with methods for organization and storing complain data, and the use of complaint data to track system-wide trends. A strong correlation was found between adoption of hydraulic modeling and methods for storing customer complaints. Future research should further characterize the connection between smart technology and customer complaint management to demonstrate how smart technologies can aid large and mid-size CWSs in resolution of customer complaints.

6. Conclusion

In this research, a survey is developed and distributed to water providers across the U.S. to characterize customer complaint management approaches by capturing the way CWSs receive, store, and use information reported by their customers. More than 500 water CWSs responded, representing a statistically significant portion of the total number of CWSs in the U.S. Respondents ranged from very small systems with less than 500 people to urban centers with more than 100,000 people served. Responses demonstrated a range in characteristics, including urbanization level, geographic region, ownership, and primary drinking water sources.

Results indicate that very large CWSs have clear funding advantages and smart advancements compared with smaller providers, including a trend of increasing digital recordkeeping by CWS size. In fact, 21% of very small water providers do not store customer complaint records at all. However, some may view these records as non-essential, given that results indicated most small providers receive less than five complaints per week. Managing customer complaints is a priority among midsize and large CWSs. Small and very small CWSs describe satisfaction with their customer complaint management, and they prioritize other management issues, such as funding deficits, infrastructure needs, and little manpower.

Managers of CWSs need information from data to make decisions about infrastructure investment and can use information to apply for additional grant funding and monitor system performance. CWSs need new tools and methodologies to improve record keeping. New complaint management systems can document complaint data automatically and securely. Further, less than half of all providers surveyed report applying complaint data to track system wide trends. CWSs may fail to detect systematic issues without the capabilities to collect data automatically and transform data into actionable information.

This research also codifies free responses, adding rich information about CWS perceptions that can lead to new research directions. The water providers report that they desire to learn more information for decision making from the data they collect. Particularly, CWSs want to use data for infrastructure improvements, trend identification, and education and outreach purposes. Finances and personnel issues are the main barriers to the digital transition of U.S. water systems, and other responses describe barriers based on challenges of managing rural systems that lack internet coverage. These responses demonstrate areas of further investigation. This research gives new insight about the types of tools that CWSs need and are willing to adopt to receive, analyze, and report customer complaints. This research identifies areas that need attention in customer complaint management and new insight to the current adoption of smart technology capabilities in the U.S. New efforts in customer complaint management systems can build on the adoption of smart technologies at water CWSs to build trust and improve customer confidence.

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Appendix A

Q1 CONSENT

- ○ I consent, begin the study (1)
- ○ I do not consent, I do not wish to participate (2)

End of Block: Consent and Info

Q2 Are you a representative of an organization that is responsible for providing water services to people or businesses (examples include: water utilities, water treatment facilities, water co-ops, sewage authorities, etc.)?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Q2 = 2

Q3 What is the name of the organization that you represent?

_____

Q4 In which state is your organization primarily based?

▼ Alabama (1) ... I do not reside in the United States (53)

Q5 In which EPA region are you located?

- Region 1 – Boston (serving CT, ME, MA, NH, RI, and VT) (1)
- Region 2 – New York City (serving NJ, NY, Puerto Rico, and the U.S. Virgin Islands)(2)
- Region 3 – Philadelphia (serving DE, DC, MD, PA, VA, and WV) (3)
- Region 4 – Atlanta (serving AL, FL, GA, KY, MS, NC, SC, and TN) (4)
- Region 5 – Chicago (serving IL, IN, MI, MN, OH, and WI) (5)
- Region 6 – Dallas (serving AR, LA, NM, OK, and TX) (6)
- Region 7 - Kansas City (serving IA, KS, MO, and NE) (7)
- Region 8 – Denver (serving CO, MT, ND, SD, UT, and WY) (8)
- Region 9 - San Francisco (serving AZ, CA, HI, NV, American Samoa, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Guam, Marshall Islands, and Republic of Palau) (9)
- Region 10 – Seattle (serving AK, ID, OR, WA and 271 native tribes) (10)
- Multiple, please specify: (11)

_____

Q6 What is the approximate average daily water demand of the population you serve?

- Less than 5 million gallons per day (MGD) (1)
- Between 5 and 19 MGD (2)
- Between 20 and 99 MGD (3)
- Between 100 and 299 MGD (4)
- More than 300 MGD (5)
- No opinion/Unsure (6)

Q7 What is the approximate size of the population your organization serves?

- Less than 10,000 people (1)
- 10,000 to 59,999 people (2)
- 60,000 to 99,999 people (3)
- 100,000 to 249,999 people (4)
- 250,000 to 499,999 people (5)
- 500,000 to 1 million people (6)

- More than 1 million people (7)
- No opinion/Unsure (8)

Q8 Is your organization public or private?

- Public (1)
- Private (2)
- Other, please explain: (3) _____
- No opinion/Unsure (4)

Q9 What use sector would you estimate makes up the largest proportion of your daily water demand?

- Residential/municipal (1)
- Industrial/commercial/energy (2)
- Agricultural/irrigation (3)
- No opinion/Unsure (4)

Q10 Which of the following best describes the area you serve?

- Rural (1)
- Suburban (2)
- Small city/city outskirts (3)
- Large city (4)
- No opinion/Unsure (5)

Q11 What is the primary water source for your service area?

- Groundwater (1)
- Surface Water (2)
- No opinion/Unsure (3)
- Other- please describe: (4) _____

Q12 Has your organization recently communicated information or an update about water services to the whole customer base?

- Yes, in the last month (1)
- Yes, in the last 6 months (2)
- Yes, in the last year (3)

- ○ No, no recent communications (4)
- ○ No opinion/Unsure (5)

Q13 What best describes your job position?

- ○ Administrator (1)
- ○ Engineer (2)
- ○ Plant Operator (3)
- ○ Customer Service (4)
- ○ Prefer not to say (5)
- ○ Other, please describe: (6) _____

Q14 "Smart" capabilities involve using digital technologies to increase efficiency, share information with the public, and improve quality of services. Is your organization using any of the following "smart" technologies?

	Yes (1)	No (2)	No opinion/Unsure (3)
Social Media (6)	○	○	○
SMS/Auto-alert customers (3)	○	○	○
Usage visualization/Customer data dashboard (8)	○	○	○
Hydraulic modelling (4)	○	○	○
Real time pressure sensors (5)	○	○	○
Advanced Meter Infrastructure (AMI)/Automatic Meter Readings (AMR) (1)	○	○	○
Digital Twins (2)	○	○	○
Artificial Intelligence (AI) or machine learning methods (9)	○	○	○

Q15 Does the budget at your organization include any plans for adopting additional smart technology?

- Yes (1)
- No (2)
- No opinion/Unsure (3)

Display This Question:
If Q15 = 1

Q16 Which of the following technology investment areas are included in your plans? Check all which apply:

- [ ] Social media (1)
- [ ] Data Visualization (2)
- [ ] Real-time pressure sensors (3)
- [ ] AMI/AMR (4)
- [ ] Hydraulic modelling (5)
- [ ] Digital Twins (6)
- [ ] AI/Machine Learning (7)
- [ ] None of these (8)
- [ ] No opinion/Unsure (9)

Display This Question:
If Q15 != 3

Q17 Please select a range of approximately how much of your budget is planned for expanding smart technologies per year.

- More than $500,000 (1)
- Between $50,000 and $500,000 (2)
- Less than $50,000 (3)
- No opinion/Unsure (4)

Q18 How challenging would it be to incorporate additional smart technologies at your organization?

- ○ Very challenging (1)
- ○ Somewhat challenging (2)
- ○ Not challenging at all (3)
- ○ No opinion/Unsure (4)

Q19 You indicated it would be challenging to incorporate additional smart technologies. Please check any statements which apply:

- ☐ Financially challenging (1)
- ☐ Not enough personnel (2)
- ☐ Personnel aren't trained for digital work (3)
- ☐ We don't see the value of these technologies for our service area (4)
- ☐ Other- please describe (5) _____

Q20 Approximately how many employees at your organization manage communications with customers about their water?

- ○ 0-5 (1)
- ○ 6-10 (2)
- ○ 11-20 (3)
- ○ More than 20 (4)
- ○ No opinion/Unsure (5)

Q21 How challenging is it to communicate with your customers?

- ○ Very challenging (1)
- ○ Somewhat challenging (2)
- ○ Not challenging at all (3)
- ○ No opinion/Unsure (4)

Q22 How are most complaints from customers received?

- ○ Calls (1)
- ○ Web portal or emails (2)
- ○ Walk-ups (3)
- ○ Mail (4)

- ○ No opinion/Unsure (5)
- ○ Other-please describe: (6) _____

Q23 How do your store records of customer complaints about water?

- ○ Entirely on paper (1)
- ○ Mostly on paper (2)
- ○ Basically the same amount on paper as digitally (3)
- ○ Mostly digitally (4)
- ○ Entirely digitally (5)
- ○ We do not store records/keep track of customer complaints (6)
- ○ No opinion/Unsure (7)

Q24 How satisfied are you with the current method of organizing and storing customer water complaints?

- ○ Satisfied (1)
- ○ Somewhat satisfied (2)
- ○ Not satisfied at all (3)

Display This Question:

If Q24 != 1

Q25 You indicated dissatisfaction in organizing and storing customer complaints. Please elaborate on what could improve your satisfaction in this area or enter "NA" if you are unsure.

_____

Q26 Approximately how many customer complaints about water services are received per week?

- Less than 5 (1)
- 6 to 25 (2)
- 26 to 50 (3)
- 52 to 100 (4)
- More than 100 (5)
- No opinion/Unsure (6)

Q27 Is there a time of year when customer complaints about water are more common?

- Spring (1)
- Summer (2)
- Fall (3)
- Winter (4)
- No difference throughout the year (5)
- Multiple seasonal changes, please specify: (6)

_____

- No opinion/Unsure (7)

Display This Question:

If Q27 = 1

Q28 During spring, which complaint type is most common from your customers?

- Odor (1)
- Discoloration (2)
- Taste (3)
- Turbidity (grit, cloudy) (4)
- Leaks/Water in road (5)
- Other, please specify: (6) _____
- No opinion/Unsure (7)

Display This Question:

If Q27 = 2

Q29 During summer, which complaint type is most common from your customers?

- Odor (1)
- Discoloration (2)
- Taste (3)
- Turbidity (grit, cloudy) (4)
- Leaks/Water in road (5)
- Other, please specify: (6) _____
- No opinion/Unsure (7)

Display This Question:
If Q27 = 3

Q30 During fall, which complaint type is most common from your customers?

- Odor (1)
- Discoloration (2)
- Taste (3)
- Turbidity (grit, cloudy) (4)
- Leaks/Water in road (5)
- Other, please specify: (6) _____
- No opinion/Unsure (7)

Display This Question:
If Q27 = 4

Q31 During winter, which complaint type is most common from your customers?

- Odor (1)
- Discoloration (2)
- Taste (3)
- Turbidity (grit, cloudy) (4)
- Leaks/Water in road (5)
- Other, please specify: (6) _____
- No opinion/Unsure (7)

Display This Question:

If Q27 = 6

Q32 Please elaborate on the primary type of complaint from customers based on the season. (ex, taste issues more common in spring). _____

Q33 Over the course of a year, about how often are there complaints from customers about the following issues?

	Rarely (1)	Sometimes (2)	Often (3)	No opinion/Unsure (4)
Odor (1)	○	○	○	○
Discoloration (2)	○	○	○	○
Taste (3)	○	○	○	○
Turbidity (grit, cloudy) (4)	○	○	○	○
Leaks/Water in road (5)	○	○	○	○
Billing (6)	○	○	○	○

Q34 Is your customer complaint data used to detect system wide trends in water quality?

- Yes (1)
- No (2)
- No opinion/Unsure (3)

Q35
Is your organization concerned about storing digital records of customer complaint data?

- Very concerned (1)
- Somewhat concerned (2)
- Not concerned at all (3)
- No opinion/Unsure (4)

Q36 Is your organization concerned about making deidentified information from customer complaint data publicly available?

- Very concerned (1)
- Somewhat concerned (2)
- Not concerned at all (3)
- No opinion/Unsure (4)

Q37 Which of these would you consider the biggest drawback of making deidentified information from customer complaint data publicly available?

- Security and privacy (1)
- Unnecessary panic or trust issues (2)
- Overloading customers with information (3)
- I don't see any problems with this (4)
- Other- please describe (5) _____

Q38 What do you like MOST about this concept?

- Detection of system wide issues (1)
- Decision making or justification for infrastructure improvement spending (2)
- Transparency and build trust (3)
- I don't see any benefit to this (4)
- Other- please describe (5) _____

Q39 In your opinion, is your customer complaint data is being used to its full potential?

- Yes (1)
- No (2)
- No opinion/Unsure (3)

Display This Question:

If Q39 = 2

Q40 You indicated more potential uses of customer complaint data. Please elaborate on potential applications of this information or enter "NA" if you are unsure.

_____

Display This Question:

If Q39 = 1

Q41 You indicated that you are fully utilizing your customer complaint data. Please elaborate on your applications of this information or enter "NA" if you are unsure.

_____

Q42 What is your initial reaction this concept?

- Strongly positive (1)
- Somewhat positive (2)
- Neutral (3)
- Somewhat negative (4)
- Strongly negative (5)

Q43 Of these capabilities, which would be the most useful to you?

- Has an online form for customers to log complaints and track work order progress (1)
- Stores a database of customer complaints (2)
- Provides an interactive data dashboard to display/ track trends in customer complaints (3)
- Displays real-time maps reported water issues that customers can view online (4)
- None of these (5)

Q44 From the list below, which best describes your thinking about this concept?

- I need it because nothing else solves this problem (1)
- This would be slightly better than what I am currently using (2)
- This is essentially the same as what I am currently using (3)

- What I am currently using is better than this (4)
- I don't see any reason to use this (5)

Q45
How much might your organization be willing to pay for such a product?

- Less than $1,999 per year (1)
- $2,000 and $4,999 per year (2)
- $5,000 and $10,000 per year (3)
- More than $10,000 per year (4)
- No opinion/Unsure (5)

Q46

Researchers are assessing the abilities of water utilities across the United States to receive and use customer complaints. If you have feedback on the survey, or issues specific to your organization, please elaborate in the box below.

End of Survey