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Understanding Multidimensional Aspects of Public Trust in the Water Infrastructure within US Shrinking Cities

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Understanding Multidimensional Aspects of Public Trust in the Water Infrastructure within US Shrinking Cities

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Dedication

I dedicate this thesis to Jeanette Butcher, the love of my life. You have been by my side since I began this academic journey and never complained. You followed me with my career in the Air Force at great personal sacrifice to both your social life and your career. I am eternally grateful for your constant love and support. I could not have succeeded here without you. I am excited for the next step in our life as we enter the chapter of parenthood. You have been a wonderful wife and will be an amazing mother.

Love,

Dan

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Abstract

Understanding Multidimensional Aspects of Public Trust in the Water Infrastructure within US Shrinking Cities

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Water contamination events, whether minor such as a boil water alert or major such as the Flint Water Crisis, are not unique or necessarily infrequent occurrences. Oftentimes, as these crises unfold, the topic of end users not trusting their water in spite of utilities ensuring the water is safe for consumption can occur due to the erosion of trust between the water provider and the end users for reasons such as breakdowns in communication or handling of the crisis. Consequentially, this can lead to end users seeking alternative—or substitute—products for tap water, such as using bottled water. This study analyzes trust as a triangular relationship between the water provider, the consumer, and the consequential action a consumer makes regarding the use of the provided tap water. We posit here that whether an individual trusts the water system and how the individual interacts with the system are interrelated. Enabling this study is a survey deployed to 21 shrinking cities in November 2019. Three questions of interest were modeled: (1) whether water provider's decisions align with the best interests of the consumer, (2) whether the tap water provided is of adequate quality, and (3) whether the water provider informs the

consumers of issues regarding the water system quickly. A Log-Likelihood Ratio Test (LRT) was used to test whether the difference in individuals' action of consuming bottled water has an impact on different aspects of trust modeled. The LRT for all three models determined there is a greater than 99% confidence that trust should be modeled differently for someone that uses bottled water as their primary water source versus someone who does not. As such, these results verify that trust is relative to the consumer actions. Select independent variables were significant in influencing trust across multiple models, including the ability to pay water bills and the number of water contamination events an individual experienced. In shrinking cities, where underutilized infrastructure is already a challenge, utilities may invest in strategies or policies aimed at building trust with certain demographics revealed in the modeling to encourage use of water received at the tap.

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Chapter 1: Introduction

Urban water crises, such as droughts limiting available water supply or water contamination events, are not unique occurrences. One such event receiving nationwide media attention was the Flint Water Crisis (Bellinger 2016), which demonstrated the known tight coupling between public health and tap water quality. As this crisis unraveled, the topic of end users not trusting their water—i.e., perceiving a high risk associated with consumption— in spite of utilities ensuring the water was safe again to consume was frequently discussed (e.g., Klayman 2016; Winowiecki 2019). Much of the erosion of trust between the water provider and the end users was credited to a breakdown in communication and handling of the crisis (Morckel and Terzano 2018). This lack of trust in the services provided by water purveyors can lead to end users seeking alternative—or substitute—products for tap water, such as using bottled water or filtering water received at the tap (Ormerod and Scott 2013; Angelo and Hentschel 2015; Yang and Faust 2019). Beyond impacting the way people interact with their system, lack of trust towards a service can have financial implications on the provider. If the end users do not see the water received as usable—regardless of whether it is in fact meeting regulatory standards—they often refuse to pay for it, leading to dramatic increases in delinquent bills (Fortin 2017). For instance, at one point, the City of Flint had issued over 8,000 past due notices to residents in an attempt to collect $5.8 million in unpaid utility bills post the Flint Water Crisis (Fortin 2017). The funding dilemma resulting from the unpaid bills causes additional issues with the water quality and as a result the trust consumers have in the water provider. Simply put, it widens the trust gap.

Understanding trust as it relates to the water sector is the first step. Trust is multidimensional and can be described as a triangular relationship between a trustor, a trustee, and potential action (Hardin 2002). The psychological state of trust provides a subjective guarantee that the trustor will gain expected results from the trustee (Rousseau et al. 1998; Liu and Wang 2019). As such, lack of public trust often impedes successful acceptance of alternatives, technologies, and policies (Stoutenborough and Vedlitz 2014; Chan and Hopkins 2017; Saad et al. 2017; Fleskens and Vos 2018). This study uses a multidimensional approach to understand the trust between the water provider (trustor), the water consumer (trustee), and whether end users frequently sought out bottle water as a substitute for tap water (potential action).

A multidimensional approach to trust allows for identifying a diverse range of factors influencing various aspects trust. Trust can be analyzed, and respective actions tailored specifically to different aspects of the triangular relationship (trustor, trustee, or potential behavior). Understanding how different aspects of trust impact end user behaviors allows the decision maker to make better-informed decisions; decisions are only as good as the information that drives them and the desired outcome of the end-user. Thus, the triangular relationship is the key. The trustee—end-user— provides the demand through using tap water or choosing to use bottled water (i.e., actions), the trustor—utility— manages, operates and plans the provision of water services, and the actions of both parties provide the information necessary to gauge relative trust with each other. The shift in perception to a triangular trust relationship model allows water authorities to develop strategies to build long-term trust relationships, which in turn improves efficiency, reduces potential costs, and improves overall water quality to end-users.

The impact of end users trusting the water received at the tap, as well as trusting those providing these services has implications for utility planning, operations, and management, as well as end-user behaviors (summarized in Table 1). For instance, Zhen et al. (2019) deployed a survey asking individuals in Shanghai if they trust their tap water, finding a correlation between trust in the government-controlled water infrastructure and the risk perception of consuming the drinking water. This underscored the issue of trust toward the water provider directly impacting trust in services received. This furthered the study of trust and the relevance of including trust as a factor in the water infrastructure planning process. In the absence of trust, water infrastructure will experience deterioration in efficiency, quality, and overall services provided. (Zimmerman 2001; Little 2002). These include the issues of unsatisfied customers who refuse to pay their bills, the underutilization of the water system, which in turn causes quicker deterioration of infrastructure and leads to reactive management for the aforementioned issues rather than becoming proactive with planning. Notably, once trust has eroded, it is challenging to rebuild (Slovic 1993), which can have long term consequences on end-user behavior in regard to water systems. Due to its complexity and subjectivity, the perception of trust has been analyzed with different meanings and nuances depending on the specific context (Davenport et al. 2007; Resnik 2011; Franceschini and Marletto 2019). For example, in May of 2000 there was a serious E. Coli outbreak in Ontario, Canada that was traced back to the water source as the delivery method. Driedger et al. (2014) studied the progression of blame and trust during and after the outbreak of the event. Their findings showed that as more information was discovered, the public cast more and more blame on the water suppliers and those with the responsibility to protect it (Driedger et al. 2014). Although the outbreak was contained, and water was brought back to safe levels, the public was slow to trust the provider again and it is unknown how long it will take to fully close the trust gap (Driedger et al. 2014). This scenario suggests that corrective efforts are necessary, but not always enough to repair trust once it has been negatively impacted.

Author(s)	Focus within Water System	Main Finding
Bondelind et al. (2019)	Drinking tap water	Trust in the decision-making process helps to establish positive consumer attitude towards drinking water. The democratic decision-making process within the drinking water sector is important to optimize efficiency with the system. The democratic process refers to the inclusion of input from the consumer rather than the municipality being the sole source of input. The results found increased positive attitudes when decision-making processes were determined to be legitimate by the consumer.
Bratanova et al. (2013)	Drinking tap water	The effect of trust on acceptance is mediated by risk perception; otherwise stated, perceived risk reduces the likelihood of trust. However, trust can be positively predicted through a history of institutional trust.
(Cuadrado et al. 2017)	Water conservation	Trust as a moderating variable on the relationship between pro-socialness and the selection of selfish water consumption strategies was studied. This refers to the concept of using all the water a farmer wants for maximum yield rather than distributing water evenly for the greatest total yield across all farmers. The results showed that under cooperative behavior, everyone profited more by increasing the total yield for distribution. However, cooperation is heavily dependent on a trusting relationship.
Driedger et al. (2014)	Drinking tap water	The shift in perceptions of trust depends on how the institutions handle the immediate issue or crisis as well as accountability measures to prevent reoccurrences of it. The E. Coli breakout in Ontario in 2000 was cited as an example; as more information was released, increased blame was cast, and trust diminished between the residents and the water supplier.
Fragkou and McEvoy (2016)	Water desalination	The study established a basis for “perceptual scarcity”. This means that water is considered unusable or “scarce” by the consumer due to a lack of trust in the water quality. The study focused on the lack of behavior change of the residents after the water concerns were addressed. The researchers found that after having potable water provided at adequate quality levels, many residents opted not to drink it due to a perceived quality issue from past experience.
Ross et al. (2014)	Use of recycled water	The trust towards the water authority increased when the authority makes fair decisions about water provision and then continues to try to treat everyone fairly.

Thaker et al. (2019)	Water conservation	Individuals with high levels of perceived collective efficacy (i.e., shared belief about the capability of a group to accomplish collective tasks) and trust in government are more likely to support government water conservation policies.
Zhen et al. (2019)	Drinking tap water	An inverse relationship between trust of water authorities and risk perception of consuming tap water exists—i.e., the more individuals trust the authorities, the less they worry about the risk.

Table 1: Selected studies connecting trust or risk perceptions with water planning, operations and management or end user behaviors

Researchers have used different methods to measure trust, typically asking such questions regarding factors thought to contribute to trust (e.g., confidence in providers) as opposed to explicitly asking the level trust of trust toward water providers and other responsible agencies (Driedger et al. 2014). Another example is the approach of using public attitude toward water management as the metric. Stoutenborough and Vedlitz (2014) surveyed the willingness of people to support a water allocation plan provided by the water provider in the event of a drought. The phrasing of "attitude toward" changes the perspective of the respondent to include a wider range of emotions but also captures trust as an overarching theme (Stoutenborough and Vedlitz 2014). In another instance, Zhen et al. (2019)—similar to this study—directly asked whether or not the residents trusted the water provider to meet the water needs. However, trust is dynamic, influenced by various economic, sociological, psychological, legal, political, and business-related factors (Siegrist et al. 2005; Buchan 2009). This adds additional challenges to establish a baseline for trust and ultimately to measure trust levels. Thus, researchers have used proxies to capture trust. For instance, Jensen and Chindarkar (2019) measured the level of trust that households have in the utility using billing accuracy as a proxy. The correlation being that if the billing is consistently accurate the household will be more likely to trust that the following bills will also be accurate as opposed to a household who regularly receives incorrect bills.

Substituting tap water with other drinking water alternatives is driven by a multitude of factors including socio-demographic characteristics, geographic characteristics, risk perceptions, and trust. For instance, Jardine et al. (1999) focused on tap water odor and established that an odor without a disclosed cause from the water provider results in a downward trend in using the tap water. The causal factor was not just the odor however, it was the odor without justification. The information sources (i.e. direct from provider, media, etc.) provided causation for switching to alternate sources (Jardine et al. 1999). Jones et al. (2006) assessed residents with private water sources and how they felt their water quality affected their drinking behavior. In this instance, the overall water quality from the private wells and cisterns was a concern because the treatment is not highly regulated and the safety precautions in municipal provided water were not equivalent. Consequentially, many of the residents turn to alternate water sources to avoid potential health risks from low quality water (Jones et al. 2006). A more recent study identified that the perception of low-quality water increased the number of residents seeking and using alternate water sources, such as bottled water (Yang and Faust 2019).

It is also important to understand how economic status can influence trust towards the water purveyor, particularly in low-income areas as literature has established that economic status is one of the top determinants of trust (Goubin and Hooghe 2020). This principle is evident in the study of Jachimowicz et al. (2017) that looked at low-income communities and measured their level of trust using a survey that determined how likely they were to take an immediate reward or a larger payout later. It showed that low-income people were more likely to take the immediate reward due to a distrust in the authorities actually providing the payout in the future (Jachimowicz et al. 2017). This relates the level of trust and the income level and demonstrates that trust in future promises from authority figures are not as commonly accepted by the poor as they are by those already living comfortably. The principle holds true in the water sector as well.

It is well established that trust is important in establishing a cooperative relationship, but the idea that trust is multi-dimensional as it relates to the water utility management has not been closely analyzed. With the basis of the triangular relationship of trust, this study addresses the differences of geographic and sociodemographic parameters influencing trust toward water infrastructure between groups of individuals with different frequency of using bottled water. Multi-dimensionality of this problem was addressed by measuring trust toward the water purveyor related to decisions made and communicating with end-users, as well as trust in the water quality of tap water received. Binary probit models were developed and the Loglikelihood Ratio Tests were conducted to determine the statistical difference of trust between the groups. Finally, to further understand why individuals sought out bottled water as a substitute to drinking water, qualitative analyses were conducted of open-ended questions. This provides valuable information for utility providers care about this information because it improves the efficiency of local water infrastructure planning and processes. The anticipated result of improved efficiency and the long-term goal is an increase in water quality.

Chapter 2: Methods

SURVEY DEPLOYMENT

Enabling the study is a survey that was deployed in December 2019 to residents who currently reside in the selected 21 US Shrinking cities (e.g., Cincinnati, Detroit, Flint, Pittsburgh, St. Louis; see Supplemental Material for full list of shrinking cities). Shrinking cities in this study are defined as cities that have experienced chronic urban decline over multiple decades post their peak population of 100,000 or more. This classification of cities often has high proportions of low-income populations (e.g., Flint, MI (40%); Detroit, MI (36%); Cleveland, OH (35%)) as compared to the national average (11.8%; U.S. Census Bureau 2018). As such, these cities are particularly relevant to explore trust and consequential human-infrastructure interactions based on the reduced trust exhibited by low-income communities. Additionally, low-income communities often receive disproportionate reduced access to water infrastructure service. Beyond possible quality challenges, there is a financial toll on residents of shrinking cities caused by the water infrastructure system. The high percentage (75-80%) of fixed costs for managing underground water systems is assumed by residents who remain in shrinking cities making them responsible for the continually increasing per capita cost of water and wastewater (Hummel and Lux 2007; Hoornbeek and Schwarz 2009; Faust et al. 2017).

Important to note, many water infrastructure systems in shrinking cities experience underutilization because the physical water network remained unchanged while population decreased over time (Faust et al. 2016). Underutilization of water infrastructure system often leads to water quality challenges such as increased water age or stagnant water throughout pipes (American Water Works Association 2002). Substituting tap water with bottled water can cause the system to further operate below capacity.

The deployed survey included questions that gauge different aspects of an individual's trust in the water infrastructure system and the water providers. The questions of interest for this study were:

(1) Do you trust the water provider to make appropriate decisions that are in the best interest of the consumer? (henceforth referred to as *Trust-Decision*).

(2) Do you have confidence in the quality of water delivered by the water provider? (henceforth referred to as *Trust-WaterQuality*); and

(3) Do you trust the water provider to inform the consumer as soon as possible when there are issues with your tap water? (henceforth referred to as *Trust-InformationASAP*).

These questions were posed on a Likert-scale¬ (strongly disagree, disagree, neutral, agree, strongly agree, and I do not know). Responses from the questions were collapsed to Agree and Disagree. Agree contains agree and strongly agree, while Disagree contains disagree and strongly disagree. As "Neutral" and "I do not know" responses as they do not indicate a stance.

To understand the human-infrastructure interactions—i.e., the actions—respondents were asked to specify the reason of drinking bottled water at their households in open-ended question:

(4) Why do you choose to drink bottled water at home?

(5) How often do you drink bottled water at home? *Never*, *Occasionally*, *Most of the time*, *Primarily*.

This behavior was collapsed to a binary parameter –frequently versus rarely—where frequent contains primarily and most of the time responses and rarely contains never and occasionally responses.

After undergoing Institutional Review Board (IRB) review at the University of Texas at Austin (receiving a status of exempt), the survey was deployed to respondents over the age of 18, selected through random sampling based on geographic quotas by a web-based survey company, Qualtrics, LLC (Qualtrics 2017). The survey was reviewed by subject-matter experts with backgrounds in survey analyses, water infrastructure management, or shrinking cities for content validation. Additionally, the survey was pre-deployed to individuals with limited knowledge about the subject (excluded from the final sample) to ensure that the survey was comprehensible to people with all levels of education. The final sample consisted of 521 valid responses.

BINARY PROBIT MODELING

A binary probit model estimates the likelihood that a dependent variable takes one of two possible discrete outcomes (0/1 in this study) depending on the conditions of the observable parameters (Aldrich and Nelson 1984). For example, when considering the outcome, *Trust-Decision*, probability that a respondent drinks bottled water for an observation i $P^{r}_{Trust\_decision}(i)$ can be estimated as follows:

$$P^{r}_{Trust\_decision}(i) = \int \Phi(\frac{\beta_{Trust\_decision}X_{Trust\_decision,n}}{\sigma}) f(\beta|\varphi) d\beta \qquad \text{Eqn. 1}$$

where Phi (Φ) is the standardized cumulative normal distribution, $f(\beta|\varphi)$ is the density function of β, and φ is a vector of parameters of that density function (mean and variance; Washington et al. 2020). All random parameters modeled are normally distributed terms. For each model, the best-fit model was identified based on the Akaike Information Criteria (AIC) values:

$$\text{AIC} = -2\log(\mathcal{L}(Trust\_decision|data)) + 2K \qquad \text{Eqn. 2}$$

which consists of the maximized log-likelihood function given the data and the model Trust, $\log(\mathcal{L}(Trust\_decision|data))$ and the asymptotic bias correction term, K (Burnham and Anderson 2004). Marginal effects are the change in a dependent variable when an independent parameter changes from 0 to 1 (for binary parameters) or there is a one-unit change in the independent variable, while all other parameters remain constant

(Cameron and Trivedi 2009). Positive marginal effects indicate an increased likelihood of the outcome of the dependent variable.

LOG-LIKELIHOOD RATIO TESTS

To assess whether respondents who frequently drink bottled water in a household statistically differ from those who rarely drink bottled water, likelihood ratio tests (LRT) were conducted for three dependent variables--*Trust-Decision*, *Trust-WaterQuality*, and *Trust-InformationASAP*. The LRT is effective when examining the transferability of results over different data sets (e.g., group, time, space; Washington et al. 2020). In this study, LRTs evaluate the alternative hypothesis (Ha) that trust is statistically different between groups of respondents with different frequency of drinking bottled water, against the null hypothesis (H0) which states that they are not statistically different (summarized in Figure 1). To be more specific, for each dependent variable three random parameter binary probit models were developed—one model with the full dataset, and two additional models that split the dataset by this who frequently versus rarely drank bottled water (Figure 2). For instance, for the dependent variable, *Trust-Decision*, the first model only contains the responses who frequently drink bottled water (n=153), the second model contains responses who rarely drink bottled water (n=218), and the last model contains the whole responses (n=371; see Figure 1).

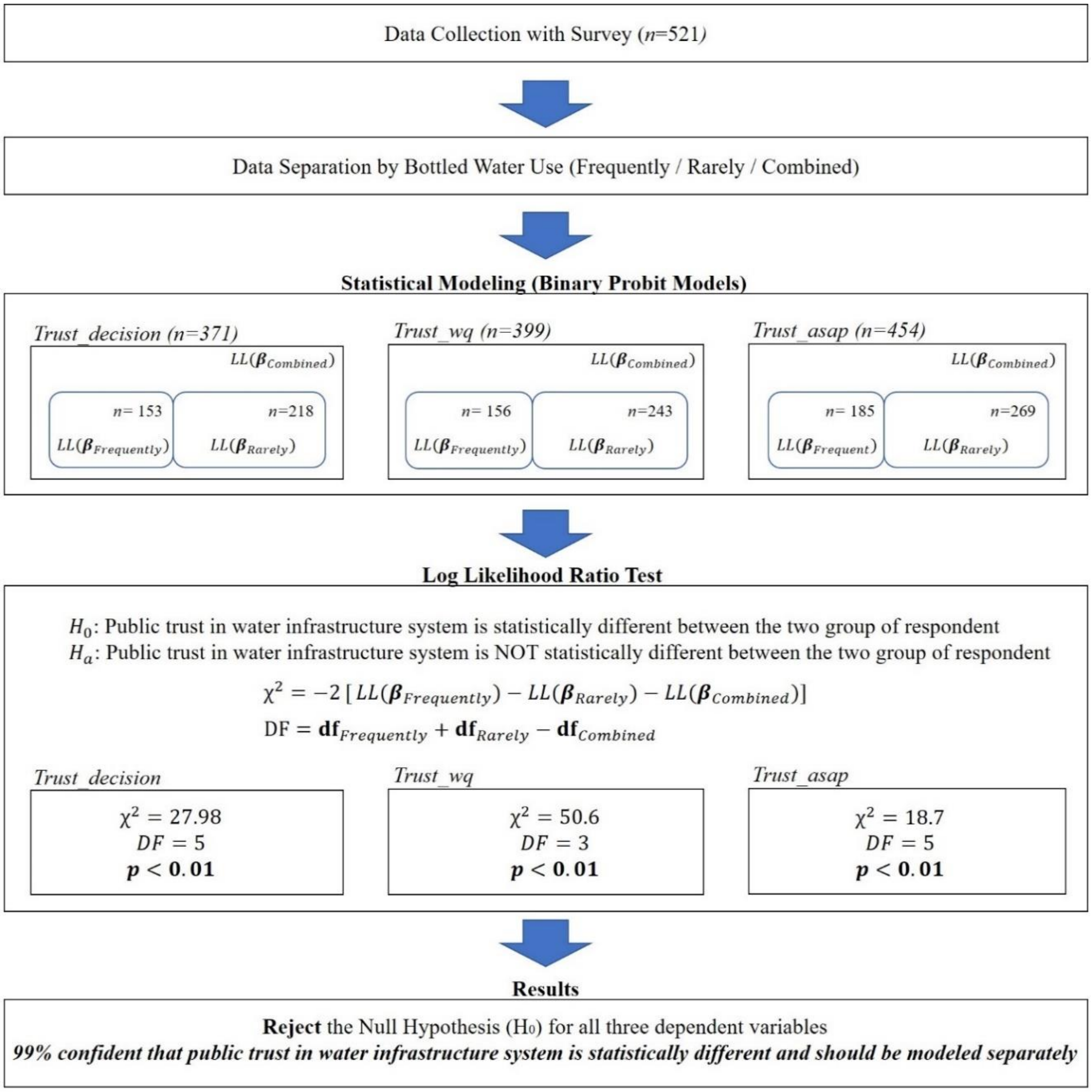

Figure 1: Summary of quantitative analyses

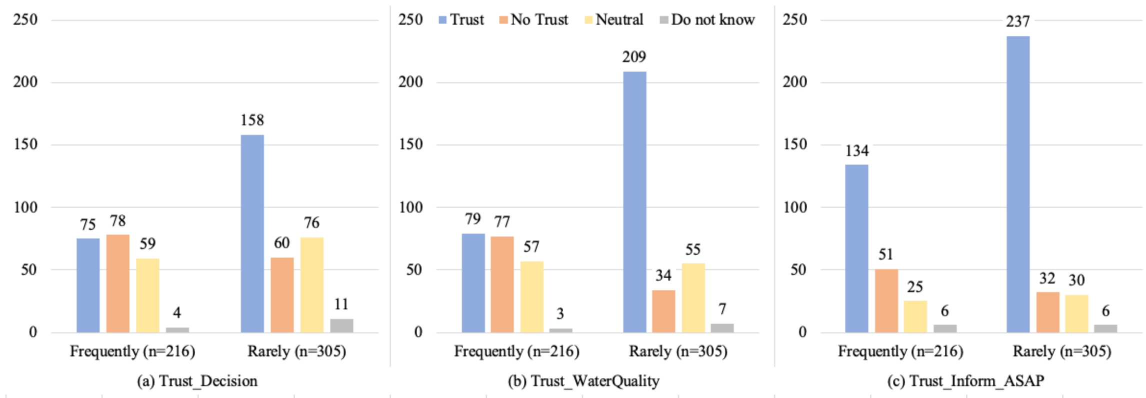

Figure 2: Trust Survey Question Responses by Category

The p-values to determine whether to reject the null hypothesis are calculated based on the Chi-square (χ^2) distributed with the degrees of freedom, which equal to the summation of the total number of estimated parameters in each of the separated models minus the number of estimated parameters in the combined model (Washington et al. 2020). The Chi-square (χ^2) values for the LRTs are calculated as following:

$$\chi^2 = -2\,[LL(\boldsymbol{\beta}_{Frequent}) - LL(\boldsymbol{\beta}_{Rarely}) - LL(\boldsymbol{\beta}_{Total})] \qquad \text{Eqn. 3}$$

where $LL(\boldsymbol{\beta}_{Total})$ is the log likelihood at convergence of the model from the combined dataset, $LL(\boldsymbol{\beta}_{Frequent})$ and $LL(\boldsymbol{\beta}_{Rarely})$ are the log likelihood at convergence of the models using the separated datasets.

QUALITATIVE ANALYSES (OPEN-ENDED QUESTIONS)

Responses from the open-ended question, asking why individuals choose to drink bottled water was classified into categories developed for the precedent survey that was also deployed to same 21 US shrinking cities in 2016 (Yang and Faust 2019). The definition of each categories is summarized in Table 2. Intercoder reliability was checked using the Cohen's Kappa, yielding a kappa value of 0.889, demonstrating consistency and validity of obtained results from the open-end question (Krippendorff 2004).

Water properties	**Reasons related to measurable water property / quality. Statements indicating that…**
Inadequate water quality	tap water fails to meet water-quality standards; bottled water thus preferred over tap water
Health perceptions	tap water is unsafe and causes health issues
Temperature	cooler temperatures, cooler than tap water, can be maintained for bottled water
Aesthetic	tap water taste, smell, appearance, texture, or color are off-putting
Personal Opinions	**Reasons related to personal perception of drinking bottled water. Statements indicating that…**
Convenience	bottled water is more convenient due to portability
Conservation	drinking bottled water helps conserve water compared with running the tap
Financial	drinking bottled is cheaper than drinking tap water
Perception of providers	**Reasons related to perceptions of users toward water providers. Statements indicating that…**
Trust	individuals express distrust of the water quality of tap water provided by local utilities and concerns regarding water-related events
Cultural	**Reasons related to cultural factors. Statements indicating that…**
Preference	individuals prefer drinking bottled water
No reason	individuals prefer drinking bottled water with no specific reasons provided

Table 2: Topical Codes (Reasons for drinking bottled water)

As with any study, limitations exist. Trust may not be directly observable and the modeling of dependent variables of trust in binary terms may be simplifying the complex concept of trust. However, this is an initial step of understanding the relationship between public trust and how people use their water they receive at the tap. The survey deployed for this study represents a cross-sectional sample, and notably public perceptions or trust are dynamic and can be shifted with new events or information (Li et al. 2015). Therefore, the respondents trust may have changed since the survey was taken. However, this allows us to test whether different considerations of trust impact bottle water use/end-use behaviors. Furthermore, as the survey was deployed among selected 21 US shrinking cities, the results cannot be generalized to cities beyond this category.

Chapter 3: Results and Discussion

The results of the LRTs for all three dependent variables—i.e., *Trust-Decision*, *Trust-WaterQuality*, *Trust-InformationASAP*— result in $p<0.01$, providing more than a 99% confidence that the null hypothesis should be rejected. As such, socio-demographic and geographic parameters influencing the probability of public trust are statistically different between respondents who frequently drink bottled water and those who rarely drink bottled water within a household (Figure 1). Otherwise stated, this means that we are over 99% sure that trust should be assessed differently for someone that uses bottled water as their primary water source and someone that chooses to use utility-provided water from the tap as their primary source.

Tables 3-5 shows the statistically significant parameters that influenced the different aspects of trust. Notably, many parameters were revealed to be statistically significant in more than one model. For instance, respondents who trust their water utility's annual water quality report showed increased likelihood of trust for all three dependent variables (Tables 3-5). This indicates that whether an individual trust the information provided by the utility has positive influences on his/her trust in the decision, trust in water quality, and trust that utilities would inform the water-related issues as soon as possible. The Utah Department of Environmental Quality (DEQ) uses the concept that water quality confidence is built through accurate and efficient reporting to further build trust with the community (Owens 2019). Their goal is to have the municipal provided tap water be used as the primary source for consumers. They suggest that trusting the water utility is just as important as trusting the water source when it comes to trust and confidence (Owens 2019). A trusting relationship between the water provider and the consumer increases trust in other areas of utility management and municipal entities. In order to develop trust in the utility, however, it requires more than just providing adequate quality of water. The quality needs to be communicated efficiently and a track record over time needs to be established. This allows the provider to become a trusted source of information and the resistance to new ideas decreases. This change in perception is only possible through the effective communication of the water providers. For this reason, the Utah DEQ has adopted a policy of transparency and published literature on the water infrastructure processes in addition to the water quality reports.

Respondents' ability to pay the water or wastewater bill was also significant across multiple models. For the group that frequently drinks bottled water, respondents who typically worry about having the financial ability to pay the bill showed decreased likelihood of trusting the water quality and decreased likelihood of trusting the water provider to inform the consumer as soon as possible when there are issues with the tap water (Table 4 and 5). In the model for the trust on decision of water provider, the parameter showed decreased likelihood of trust for the group who rarely drinking bottled water (Table 3). This is unsurprising for a few reasons. One, previous work found that low-income communities are less likely to trust authorities or providers (Brandt et al. 2015; Ananyev and Guriev 2016). Second, as previously mentioned, purchasing bottled water is an additional financial burden. For those who are struggling with their bills and yet are frequently drinking bottled water, this financial burden my consist of a disproportionate percentage of their income relative to someone that does not worry about paying their bills.

The relationship between trust and wealth may capture a dependency. This is particularly relevant here as shrinking cities have higher rates relative to the national average (U.S. Census Bureau 2018).

Another factor that appeared in multiple models was the number of water contaminations (e.g., boil advisories, reports of high lead or other chemicals) the city the respondent lived in has experienced. For the group who frequently drink bottled water, respondents who experienced less than five issues in past 10 years were more likely to trust the decision and that the water provider would inform them of issues as soon as possible (Tables 3 and 5). On the other hand, respondents who experienced more than five issues were less likely to trust the water quality for the same group (Table 4). As the number of incidents acknowledged increases, the level of trust decreases by nature of consistency. Similarly, the awareness of the water contamination issues that occurred outside of the city showed decreased likelihood of trusting the quality of the tap water for both groups (Model for Frequently and Rarely Drinking Bottle Water; Table 4). This captures that the water contamination issues, even those that may not directly affect the respondent's household can influence trust towards water quality. Conversely, when the respondents are aware of fewer water contamination events, their trust increases. Contamination is the primary factor regarding the quality of water. Therefore, it makes sense that Table 5 would show significant results regarding the contamination concerns. This means that known contamination issues become indicative of trust within the water sector and influence the level of trust that exists.

Geographic parameters (e.g., city, state) that were statistically significant in influencing *Trust-Decision* and Trust-Inform-ASAP were also identified and shown in Tables 3 and 5, respectively. Important to note, the geographic parameters were all modeled as fixed variables, indicating that geographic locations have homogeneous impact. This shows that the trust is influenced by the localized factors, such as policies and communication strategies of the local municipalities or utilities. People that live in the same geographic location are more likely to have similar attitude (i.e., little variance regarding the data). Interestingly, *Trust-WaterQuality* was the only dependent variable that no geographic parameters were revealed in the model development (Table 4). This aligns with the finding that respondents who are aware of water contamination issues occurred in other cities showed decreased likelihood of trust on water quality for both groups of bottled water users (Table 4). The media coverage on those contamination events outside of their cities may not impact the trust on the water providers, however, it may generate the anxiety and distrust that their water could also have quality issues. This may be introducing that there are porous lines with regards to how we perceive water quality and the actual quality, and the consequential way we use the water we receive.

Table 3 summarizes the parameters influencing the likelihood of trust that the water providers is making decisions in the best interest of the consumers. It is interesting that trust in the information delivered by the utility providers is the only common significant factor between people who frequently use bottled water and those who rarely drink bottled water. All other significant factors are unique to whether users drink bottled water frequently versus not. The finding aligns with the result of LRT that the two groups should be modeled separately. This tells utilities to develop separate strategies of developing trust relationship with the residents who choose to frequently drink bottled water and those who rather directly consume the tap water. It is important to note the location factors that affected the trust of individuals. New Jersey was significant for respondents who frequently drank bottled water, showing decreased likelihood of trust, while Ohio was significant for respondents who rarely drank bottled water, showing increased likelihood of trust. This suggests underlying issues in New Jersey that affect both the water quality and the communication effectiveness. The Natural Resources Defense Council (NRDC) has investigated the water concerns in New Jersey and validated the concerns. In what is dubbed the “Newark Water Crisis”, unsafe levels of lead have been found in the drinking water. The organization suggests the municipality and water provider are at fault for neglecting to properly maintain the infrastructure (NRDC 2019). It is unknown if this is a specific incident that respondents referred to, but it illustrates why the location factors are in fact significant to this study.

Independent Variable	Frequently			Rarely		
	Parameter (t-stat.)	SD (t-stat.)	Marginal Effects	Parameter (t-stat.)	SD (t-stat.)	Marginal Effects
Constant	-0.87 (-2.71)	-	-	0.87	-	-
Number of water contamination issues experienced within the city (1 if less than 5 in past 10 years, otherwise 0)	1.18 (3.78)	*fixed*	0.47	-	-	-
Trust on water quality information (1 if trust water quality information delivered by utility providers, otherwise 0)	1.71 (5.23)	*fixed*	0.48	1.34 (4.93)	*fixed*	0.39
Number of cars (1 if household owns more than one car)	-0.84 (-2.55)	*fixed*	-0.33	-	-	-
New Jersey state indicator (1 if reside in New Jersey state, otherwise 0)	-1.77 (-2.98)	*fixed*	-0.70	-	-	-
Born where currently residing (1 if born where currently residing, otherwise 0)	1.91 (5.53)	*0.18 (0.59)*	0.07	-	-	-
Age (1 if over 50, otherwise 0)	-	-	-	-1.03 (-2.71)	*fixed*	-0.30
Filtered water use (1 if drink filtered water at home, otherwise 0)	-	-	-	-0.46 (-1.90)	*fixed*	-0.14
Education (1 if have college degree or post graduate degree, otherwise 0)	-	-	-	-0.61 (-2.45)	*fixed*	-0.18
Primary source of news (1 if TV is the primary source of news, otherwise 0)	-	-	-	0.53 (1.85)	*fixed*	0.16
Primary source of news (1 if social media is the primary source of news, otherwise 0)	-	-	-	-0.74 (-2.53)	*fixed*	-0.22
Ohio state indicator (1 if reside in Ohio state, otherwise 0)	-	-	-	0.65 (2.22)	*fixed*	0.19
Ability to pay utility bill (1 if worry about having the ability to pay water or wastewater bill, otherwise 0)	-	-	-	-1.33 (-4.03)	2.09 (4.25)	-0.39

Log likelihood at convergence	*-74.33*	*-95.64*
AIC	*162.7*	*211.3*
Number of observations	*153*	*218*

Table 3: Parameters influencing the likelihood of Trust on decision

Table 4 outlines the significant parameters relative to the likelihood of trust in the water quality provided to the consumers. Three variables were statistically significant for both frequent and rare bottled water users—home ownership, awareness of water contamination, and trust in the information provided by the water utility providers. The factor of home ownership is not surprising because a homeowner pays both utility bills and property taxes which makes them more personally invested in the quality of water that comes to their home. The same is true for awareness of water quality issues and trusting the information provided. If a consumer understands the water quality information given by the utility provider, the trust in the quality of the water from the water provider becomes more certain. In other words, effective communication builds trust. Another key takeaway from is the concept of perception molds reality for an individual. This is evident in the responses relative to the number of water contamination issues experienced. Those who frequently drank bottled water reported experiencing water contamination issues whereas those who rarely drink bottled water reported not remembering any water contamination issues. This indicates that the respondents are perceiving the water contamination issues differently and therefore, the reality of their drinking water situation aligns with their confidence in the contamination issues presented by the providers.

Independent Variable	Frequently			Rarely		
	Parameter (t-stat.)	St. Dev. (t-stat.)	Marginal Effects	Parameter (t-stat.)	St. Dev. (t-stat.)	Marginal Effects
Constant	1.39 (2.97)	-	-	1.36 (2.95)	-	-
Age (1 if between 36 and 50, otherwise 0)	0.10 (0.24)	2.09 (3.92)	0.04	-	-	-
Gender (1 if female, otherwise 0)	-	-	-	-0.78 (-2.29)	*fixed*	-
Marital status (1 if single, otherwise 0)	-0.31 (-0.87)	*1.54 (4.21)*	-0.12	-	-	-
Ability to pay utility bill (1 if worry about having the ability to pay water or wastewater bill, otherwise 0)	-1.01 (-3.05)	*fixed*	-0.40	-	-	-
Home ownership (1 if homeowner, otherwise 0)	-0.72 (-2.12)	*fixed*	-0.29	0.94 (2.76)	*fixed*	-
Awareness on water contamination issues (1 if aware of any water contaminations occurred in other cities, otherwise 0)	-0.87 (-2.15)	*fixed*	-0.34	-0.57 (-1.53)	1.37 (5.20)	
Number of water contamination issues experienced within the city (1 if more than 5 in past 10 years, otherwise 0)	-1.69 (-4.65)	*fixed*	-0.67	-	-	-
Number of water contamination issues experienced within the city (1 if don't know/remember any in past 10 years, otherwise 0)	-	-	-	-0.64 (-1.88)	*fixed*	-
Trust on water quality information (1 if trust water quality information delivered by utility providers, otherwise 0)	1.32 (3.70)	*fixed*	0.52	1.57 (3.94)	0.93 (3.24)	-
Log likelihood at convergence		*-69.35*				
AIC		*158.7*				
Number of observations		*156*				

Table 4: Parameters influencing the likelihood of Trust on water quality

Table 5 compares the parameters influencing the likelihood of a consumer's trust that the water provider will inform the consumer as soon as possible when issues arise. Similar to the result for *Trust_Decision* model, there was a distinction between the two groups in trust that utilities would inform an issue as soon as possible. Trusting the water quality report is the only common significant factor between frequent and rare bottled water drinkers, showing an increased likelihood of trust for both groups. This is expected because the water quality report is the method a water provider uses to announce issues with the water. The water quality report accuracy and timeliness are directly related to the trust in information flow and is not independent to anyone. When the frequency of using bottled water is used as the measure of trust it is expected that the water quality report would become a basis for measuring the adequacy information flow. This validates the findings of the Utah DEQ as well. A well communicated report along with a policy of transparency is significant when establishing trust (Owens 2019). Another key finding is the employment status. The economic status relationship to trust has been discussed earlier in this paper and this variable confirms its significance. However, it is only significant to those that rarely use bottled water which aligns with the previous economic discussion regarding the ability to pay bills.

Independent Variable	Frequently			Rarely		
	Parameter (t-stat.)	SD (t-stat.)	Marginal Effects	Parameter (t-stat.)	SD (t-stat.)	Marginal Effects
Constant	0.77 (2.49)	-	-	1.00 (5.02)	-	-
Perception on population change (1 if perceived no significant change in population over past 4 decades, otherwise 0)	-0.99 (-3.41)	*fixed*	-0.21	-	-	-
Ability to pay utility bill (1 if worry about having the ability to pay water or wastewater bill, otherwise 0)	-0.56 (-2.09)	*fixed*	-0.12	-	-	-
Number of water contamination issues experienced within the city (1 if less than 5 in past 10 years, otherwise 0)	0.86 (3.19)	*fixed*	0.18	-	-	-
Trust on water quality report (1 if trust the utility's annual water quality report, otherwise 0)	1.12 (3.30)	*fixed*	0.23	1.40 (4.38)	0.66 (2.75)	0.16
Maryland state indicator (1 if reside in Maryland state, otherwise 0)	-1.08 (-1.92)	*fixed*	-0.23	-	-	-
Marital status (1 if single, otherwise 0)	0.90 (2.44)	2.08 (4.61)	0.19	-	-	-
Education (1 if have college degree or post graduate degree, otherwise 0)	-	-	-	-0.68 (-2.72)	*fixed*	-0.08
Employment status (1 if Employed for wages/salary, otherwise 0)	-	-	-	0.52 (1.98)	*fixed*	0.06
Log likelihood at convergence		*-85.63*			*-84.24*	
AIC		*187.3*			*178.5*	
Number of observations		*185*			*269*	

Table 5: Parameters influencing the likelihood of Trust that inform as soon as possible

The statistical models demonstrate which sociodemographic variables influence trust based on how the respondents interact with their tap water, but do not tell us why. Table 6 summarizes the identified themes of why respondents choose to drink bottled water over tap water, separated for those who frequently drink bottled water and those who rarely. Overall, the three aspects of trust (i.e., *Trust_Decision*, *Trust_WaterQuality*, *Trust_ASAP*) showed similar results within the same group. One of the most important difference is that amongst the responses from those who frequently drank bottled water, 22 responses indicated trust as a reason, whereas those who rarely drink bottle water did not have this code emerge. Another notable difference is that people who frequently drink bottled water were primarily concerned with the water properties and quality, accounting for over 60% of the responses. Whereas those who rarely use bottled water navigated towards this option due to personal opinions, accounting for over 50%. This also aligns with the results from LRT indicating that the two groups should be modeled separately.

The differences in qualitative responses relates to the idea that individuals have different degrees of vulnerability in different situations and different risk perceptions in decision making (Mayer et al. 1995; Stern and Coleman 2015). The reason someone trusts is personal. People ultimately choose what factors affect their level of trust on the water provider the most. For example, some respondents based their trust on the quality of water that comes from the tap by associating good water quality with a trustworthy provider. Whereas others base trust on the level of communication and assurance the water is safe. These individuals judge more by the social interaction rather than the quality of product. Each rationale is valid, but individual to the consumer.

	Frequent Bottled Water			Rarely Bottled Water		
Categories	***Trust-Decision***	**Trust_WQ**	**Trust_ASAP**	**Trust_Decision**	**Trust_WQ**	**Trust_ASAP**
Total	93	98	161	46	56	72
Water-properties-related	58 (62%)	63 (64%)	107 (66%)	16 (35%)	18 (32%)	25 (35%)
Aesthetic	33	38	59	9	11	18
Inadequate Quality	15	16	24	3	3	2
Health/Safety	9	7	20	2	2	3
Temperature	1	2	4	2	2	2
Personal Opinions	18 (19%)	19 (20%)	24 (15%)	25 (54%)	31 (55%)	35 (48%)
Convenience	13	13	19	25	30	34
Conservation	3	2	3	0	1	1
Financial	2	4	2	0	0	0
Perception toward providers	6 (7%)	4 (4%)	12 (8%)	0 (0%)	0 (0%)	0 (0%)
Trust	6	4	12	0	0	0
Cultural	11 (12%)	12 (12%)	18 (11%)	5 (11%)	7 (13%)	12 (17%)
Preference	8	8	14	0	3	8
No reason	3	4	4	5	4	4

Table 6: Self-identified reasons for using bottled/filtered water

Chapter 4: Conclusion

Trust in the water sector is essential to the efficient management of water infrastructure and directly impacts the perceived quality of water provided to the consumer. When considering public trust towards water utility services and the consequential service received at the tap, the trustor, the trustee, and consequential actions are key components (Stern and Coleman 2015). The Flint water crisis is a good example of the deterioration that can occur in the absence of trust. The citizens of Flint Michigan were exposed to poor quality water and then the local government and water provider were not transparent with the public when the issues were found. This lack of communication and continuing to provide the sub-par water led to a large distrust between the public and the provider. This trust gap continued to worsen with time and the water infrastructure has suffered (Bellinger

2016). The results of this study found that socio-demographic and geographic parameters influencing public trust are in fact statistically different between respondents who frequently drink bottled water and those who rarely drink bottled water within a household in US shrinking cities. Most of the parameters indicating knowledge of the perceptions regarding, and attitudes toward water infrastructure were revealed to be statistically significant in more than one dependent trust variables. This indicates that the relationship between the provider and the consumer is affected by the perception the consumer has of the provider and the subjective attitude a consumer develops from personal experience.

Notable statistically significant parameters include the individuals' trust in water quality reports, trust in the information provided by the utilities, and the awareness of the water contamination events that affect the water infrastructure system within the city. In addition, such parameters showed different cardinality of the impact on trust. In other words, some of the parameters that were significant across multiple models showed changes in trust (increased or decreased) among the three models. These findings are important because they demonstrate that trust is multidimensional; one single aspect of trust cannot comprehensively represent trust toward the water infrastructure system. The multi-dimensional aspect of trust influences the human-infrastructure interactions by providing additional concepts to consider when determining whether trusting relationships exist. If the trusting relationship does not exist or is strained, it also provides multiple factors for consideration when attempting to improve the trust relationships and as a result the efficiency of the water infrastructure system as a whole. Interestingly, geographic parameters were revealed as statistically significant for the *Trust-Decision* and *Trust-Inform-ASAP* models, while no geographic parameters were significant in *Trust-WaterQuality* model. Furthermore, all the geographic indicators were modeled as fixed parameters. This indicates that the two aspects of trust (i.e., trust on decision, trust that water providers would inform the water issues as soon as possible) are more influenced by localized factors, such as the communication strategies of local water providers. On the other hand, the trust on water quality is more impacted by a broader range of factors most notably nationwide media attention regarding water contamination events.

The clear distinction between the group who frequently drink bottled water and rarely was further explored through a qualitative analysis which identified why an individual chooses to drink bottled water. Water properties were the leading factors for a personal decision to use bottled water, including water aesthetics and perceived health risk. This provides valuable information for the infrastructure manager or city officials to better understand causes for the action of using bottled water, which provides data for comparison when attempting to manage the underutilized water system in shrinking cities. The results also provide valuable insights to the water providers to effectively develop communication strategies dependent on trusting relationships. This was the case with the Utah DEQ. They developed a policy of transparency and based the decision on the notion that effective communication builds trust (Owens 2019). Further, this study also provides motivation to develop policy, accurately accounting for water usage needs and the ability to focus on consumer needs and concerns proactively rather than reactively.

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