Temporal Dynamics of Willingness to Pay for Alternatives That Increase the Reliability of Water and Wastewater Service

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Abstract: Changes in public perceptions affect infrastructure projects, policies, and revenue streams. As such, utilities should leverage these dynamic perceptions for a variety of reasons, including identifying strategic times to increase operational revenues through rate changes or billing structure, implementing capital projects or management approaches, or integrating new policies. This study focuses on assessing the temporal variations of stated willingness to pay for improved water and wastewater service of residents in 21 shrinking US cities. This classification of cities was selected due to the fiscal constraints placed on utilities because of the reduced number of customers from that which the original system was designed to serve. Furthermore, a consequence of this decline, a high proportion of low-income residents are paying high per-capita costs. Enabling this study are survey data collected in 2013 and 2016. Random-parameter Tobit regression models are used to identify geographic and sociodemographic factors influencing this stated willingness to pay. A likelihood ratio test confirmed a statistically significant shift between the surveys in the residents' stated willingness to pay. Model results reveal that between the timeframes of the deployed surveys, the influences of geographic (e.g., Michigan, Ohio) and sociodemographic factors (e.g., age, income) changed as well. Utilities may benefit from using the identified parameters to develop strategies (e.g., outreach programs, targeted education, media advertisements, inclusion in planning) to target specific groups. Similarly, using the geographic parameters may also present an opportunity to increase operational revenue due to higher willingness to pay by residents. In general, this study highlights that public perceptions should be periodically investigated to continually identify times of greater public support for various utility efforts under way. **DOI: 10.1061/(ASCE)CO.1943-7862.0001668.**

Introduction

Public perceptions change with time, new information, and events (Krewski et al. 2006; Li et al. 2015). These public perceptions are important to consider by utilities, civil engineers, and other decision makers as they affect infrastructure projects, policies, and revenue streams. Notably, the dynamic nature of perceptions can be strategically leveraged to identify opportunistic times to increase billing revenues through rate changes or billing structures, implement projects, or integrate policies, for example. These perceptions can also limit the success of projects (e.g., Bowman 2017; Waxmann 2015; DiChristopher 2017) or policies (e.g., Lorenzoni et al. 2007; West et al. 2010; Leung et al. 2013) and, at times, even halt or reverse them. For example, the construction of the Keystone Pipeline was delayed in 2015 due to public disapproval but was later approved with public support in 2017 (DiChristopher 2017). Changes in public opinion have affected the policy of privatizing critical infrastructures (Hall et al. 2014). For example, voters in Atlanta passed a measure to privatize their water systems, only to later reject the decision once public perceptions had shifted (Jehl 2003).

Similar to the change in perceptions of the projects and policies discussed earlier, there exists a temporal variation of the stated willingness to pay (WTP) for infrastructure services. Previous studies define stated WTP as the stated amount that a consumer is willing to pay for specific goods or services (e.g., Rollins et al. 1997). Notably, this differs from revealed WTP, which is the actual amount that a consumer pays for a good that is revealed through behaviors. This stated willingness to pay for infrastructure services can have direct implications on the operating revenues of utilities, funds available for maintenance and rehabilitation, or revenue for new projects. In 2016, voters in Portland, Oregon, approved a 4-year gas tax ($0.10/gal.) to update road infrastructure for the improvement of the existing service. Importantly, lawmakers failed early on to pass this tax in Portland in 2015 but later succeeded with the shifting public perceptions due to providing the public with a list of specific projects that would benefit from the tax (Njus 2016).

These changing perceptions over time are influenced by geographic location, sociodemographic parameters, or external factors such as proximity to events or media coverage (Faust et al. 2016a; Osman and Faust 2017). Given its possible impact on infrastructure systems, the dynamic nature of public perceptions needs to be explored. This study seeks to accomplish three objectives: (1) assess the temporal dynamics of public perceptions with regards to stated WTP for the improved level of service (LOS) reliability of water

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and wastewater systems between 2013 and 2016; (2) present an approach to evaluating the drivers of stated WTP; and (3) discuss the implications that stated WTP and accompanying drivers may have on the provision of water and wastewater services and infrastructure projects. The results of this study fill gaps in the literature and practice in terms of understanding the temporal characteristics of stated WTP and the attendant geographic and demographic drivers. In fact, this study aims to show how the geographic and demographic drivers of public perceptions may be susceptible to exogenous factors (e.g., proximity to events, policy changes) within cities or nearby areas. It explores WTP in the context of shrinking US cities. A characteristic of shrinking cities is fiscally strained utilities that serve a high proportion of low-income residents. Consequent to this decline, customers—often of low income—pay high per-capita costs due to the fixed costs of water and wastewater infrastructure and fewer customers supporting the system because of the chronic population decline. These cities, with their limited funds and resources for maintenance and capital investment, may benefit from using the drivers identified in this study to develop strategies for the sustainable operations and management of infrastructure services provided. Increases in revenue, even small percentages, can shift shrinking cities from reactive to proactive maintenance and allow for funding new projects.

Background

As noted by Flyvbjerg et al. (2004), the average lifespan of an infrastructure project is 13 years. Notably, water and wastewater infrastructure projects are often used for longer at an average of 25 years (Slack et al. 2003). Over this lifespan, public perceptions toward infrastructure alternatives, levels of service, and WTP are likely to shift because of the ephemeral nature of public views. Indeed, the public can oppose a project due to external factors, such as proximity to events in similar cities, negative media coverage, or the economic state of a community (Valentin and Bogus 2012; Naderpajouh et al. 2014). Researchers often try to capture these perceptions using cross-sectional methods, such as semistructured interviews, focus groups, or surveys (e.g., Taylor et al. 2012; Ma et al. 2015; Lewis et al. 2017). Such methods capture the public's perception only in a specific period; they cannot be used to assess public reaction to certain events that may arise or provide decision makers with up-to-date information (Li et al. 2015; Whittington et al. 1990).

In addition to cross-sectional assessments, researchers have applied other survey analysis techniques to consumer-stated WTP to gain insights into users' perceptions of the value the services provide. Such techniques have included contingent valuation methods (CVMs), an economic valuation of a nonmarketed good, to gauge users' WTP for water infrastructure services (e.g., Rollins et al. 1997; Fujita et al. 2005; Hensher et al. 2005; Alcubilla and Lund 2006; Banda et al. 2007; Genius et al. 2008; Lewis et al. 2017). These studies have validated the use of CVMs on assessing public WTP for infrastructure services and identified the factors that influence this perception. Banda et al. (2007) applied a CVM to estimate South African residents' WTP for quantity and quality of water when there existed no standard price on the quantity and quality of water. With the residents of Iquitos, Peru, Fujita et al. (2005) used a CVM to measure their WTP for water and sanitation services and to establish tariffs for these services. In 2002 in Canberra, Australia, Hensher et al. (2005) sent a stated preference survey to 211 households that listed choices between various services and their respective prices. The results from these studies support the idea that residents put a monetary value on water sector service reliability. This is further verified by the association between a greater WTP and reduced service interruptions (Hensher et al. 2005). Data on WTP collected in Crete, Greece, by Genius et al. (2008) found that residents were willing to pay a 17.6% increase in their bill for improvements to water and wastewater quality. These studies show, through different examples, the applicability of CVMs to measuring end-user-stated WTP for water and wastewater services.

Although WTP studies have shed light on factors that influence the stated WTP, they often yield a high proportion of zeros (Hensher et al. 2005; Genius et al. 2008; Veronesi et al. 2014; Faust et al. 2016b, 2018). Notably, a challenge to CVMs is differentiating between s-called true and protest zeros. True zeros represent a completely valueless amenity to the respondent, while protest zeros represent respondents' rejection of a portion of the amenity or a respondent's perception that another entity should be responsible for the amenity (Lindsey 1994; Fonta et al. 2010; Tentes and Damigos 2015). Previous studies overcame this challenge by coupling CVMs with certain statistical methods, for example, the full information maximum likelihood estimator (Fonta et al. 2010), the four-hurdle model (Yu and Abler 2010), and discrete response logit models (Hanemann 1984).

Expanding on the combination of statistical modeling and CVM, researchers have also used the Tobit regression procedure for overcoming large numbers of zero responses (Bowker et al. 2003; Cho et al. 2008). Cho et al. (2008) noted that Tobit models accounted for the bias introduced by true zero and protest zero responses concerning respondents' stated WTP for land conservation easements in North Carolina. Previous studies expanded the applicability of the Tobit model on the statistical analysis of stated WTP by incorporating the finite-mixture or latent-class approach to account for unobserved heterogeneity and address issues associated with statistical modeling and survey analysis (Beharry-Borg and Scarpa 2010; Cooper et al. 2018; Faust et al. 2018). This latent-class estimation approach accounts for unobserved heterogeneity by classifying observations into distinct classes based on similar characteristics. One drawback to this approach is that the number of classes is usually small, which results in a coarse approximation of the distribution of heterogeneity (Behnood et al. 2014; Pahukula et al. 2015). Additionally, the latent-class approach does not account for variation within a class by assuming parameter homogeneity within each class (Pahukula et al. 2015; Mannering et al. 2016).

Of particular interest to this study are individuals' stated WTP for improved water and wastewater LOS reliability—defined as uninterrupted, clean water at an adequate pressure—in shrinking US cities. Notably, this study does not consider the investment for new infrastructure alternatives; however, an increased WTP may result in available revenue streams for such alternatives. Shrinking cities are defined as medium and large cities that have, over multiple decades, experienced chronic urban decline of at least 30% or more after a population peak of approximately 100,000 persons or more. This subset of public perceptions, stated WTP, is assessed on residents of shrinking cities because the physical footprint of the infrastructure systems is much greater, due to the large peak populations, than that needed to support the nonuniform population across the city. This nonuniform population poses many operational and quality challenges to both utility providers and end users, such as high water ages, stagnant water, and settlement of solids within wastewater systems (Faust et al. 2016b). Additionally, due to declining populations and the consequent decreasing number of users in systems, per-capita costs for infrastructure services increase (Faust et al. 2016b). The burden of the increased costs of maintaining and operating the high fixed-cost systems typically fall on those least equipped to shoulder such burdens, as urban decline results in higher poverty rates (Pallagst 2009; Faust et al. 2016b).

The operating environment of shrinking cities—underutilized systems and reactive maintenance of these systems—often results in a reduced LOS provided to users (Faust et al. 2016b). Several studies have shown, though, that those of lower income are willing to pay for improved goods and services (Knetsch 1990; Whittington et al. 1990; Faust et al. 2015, 2016b). Faust et al. (2018, 2016b) found that in 2013 residents in shrinking cities were willing to pay increased rates if it resulted in perceived increases in their water and wastewater levels of service. However, in light of a dynamic operating environment, this WTP may change—either increasing or decreasing.

Similarly, Whittington et al. (1990) found that residents in a rural Haitian city were willing to pay more for improved water services, despite annual household incomes being approximately US$800. These findings suggest that incorporating public perceptions into the decision-making process can result in increased functioning revenues (in this case, increasing rates for improved levels of service) for utilities and project managers. Similar to the aforementioned case in Portland where the public perceived the current city transportation infrastructure as inadequate, the public supported gas and sales tax increases for capital projects and future infrastructure investments to improve service (Njus 2016). This finding underscores the idea that public perceptions are dynamic and that the success of infrastructure projects can depend on capturing them at specific times.

Methodology

Survey Development and Deployment

A CVM may be used to assess the temporal variation of WTP among residents in shrinking US cities. In 2013, a survey was sent to 21 shrinking US cities to assess public perceptions of water and wastewater infrastructure service received and of alternatives implemented across the cities. The survey included questions to capture the public's attitudes, awareness, and understanding of water and wastewater infrastructure service, operations, management, and potential physical alternatives within their city. Of interest to this study are the survey questions pertaining to the quality of water obtained from the tap and the stated WTP for improved water and wastewater service (specific questions shown in what follows). Between the time of the original survey (2013) and 2016, the media increased its attention on water sector infrastructure issues nationwide (e.g., Schwirtz 2013; Satija 2014; FEMA 2013; CNN Library 2017). As a result, in 2016 researchers sent to the same cities a second survey, one that included questions from the initial survey and new questions as well. These shrinking cities were as follows: Akron, Ohio; Baltimore, Maryland; Birmingham, Alabama; Buffalo, New York; Camden, New Jersey; Canton, Ohio; Cincinnati, Ohio; Cleveland, Ohio; Dayton, Ohio; Detroit, Michigan; Flint, Michigan; Gary, Indiana; Niagara Falls, New York; Pittsburgh, Pennsylvania; Rochester, New York; Saginaw, Michigan; Scranton, Pennsylvania; St. Louis, MIssouri; Syracuse, New York; Trenton, New Jersey; and Youngstown, Ohio (Fig. 1).

Prior to distribution, researchers obtained approval from the Institutional Review Board (IRB) for both surveys, which were also reviewed by more than 10 subject matter experts (SMEs) in the fields of survey analysis, water infrastructure, shrinking cities, or a combination thereof. Both surveys were predeployed to 25 individuals—not included in the final sample—to assess accessibility of the survey questions and to ensure that the survey captured the intended data. Notably, the length of the survey and the attention filters were considered part of the internal validation

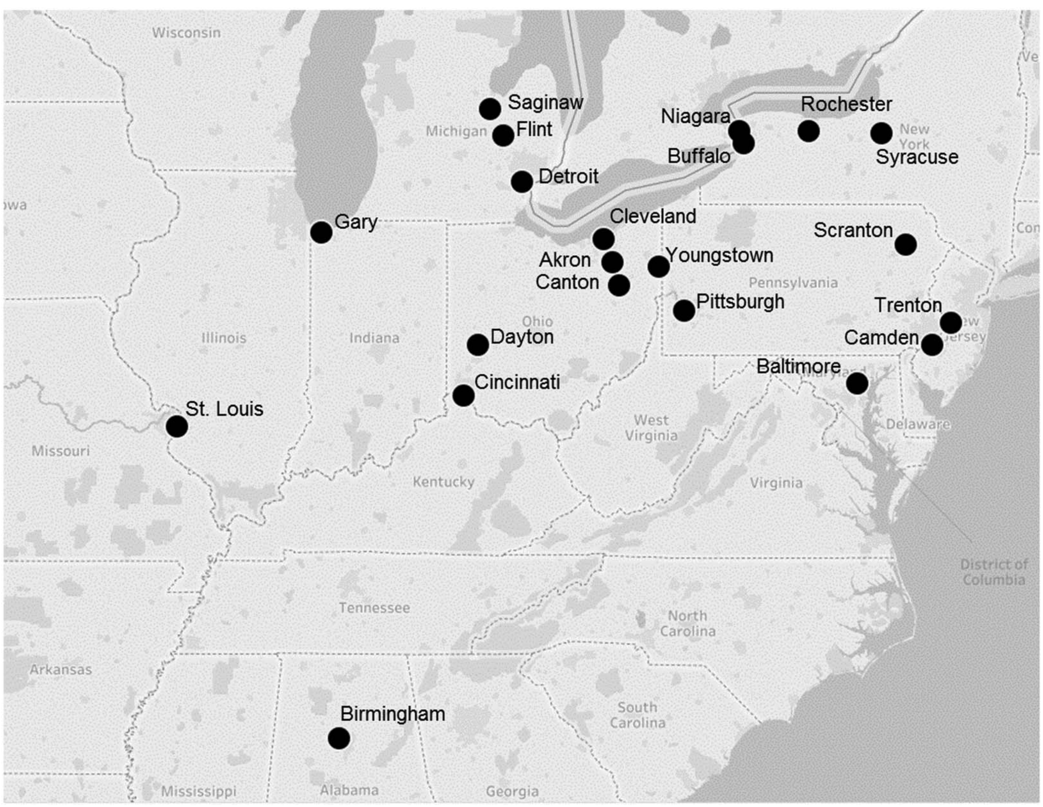

Fig. 1. Locations of survey respondents in shrinking US cities. (Background map © OpenStreetMap contributors.)

Table 1. Select descriptive statistics from 2013 and 2016 surveys

Parameters	Min/Max	Average 2013	Average 2016
Male (1 if male, 0 otherwise)	0/1	0.603	0.317
Age (1 if between 18 and 35, 0 otherwise)	0/1	0.290	0.610
Marital status (1 if single, 0 otherwise)	0/1	0.356	0.437
Household size (1 if single household, 0 otherwise)	0/1	0.216	0.144
Household size (1 if household size greater than two individuals, 0 otherwise)	0/1	0.428	0.561
Education (1 if high school diploma is highest level of education, 0 otherwise)	0/1	0.347	0.326
Education (1 if college degree is highest level of education, 0 otherwise)	0/1	0.335	0.401
Employment (1 if employed or self-employed, 0 otherwise)	0/1	0.489	0.685
Income (1 if individual income between $0 and $19,999, 0 otherwise)	0/1	0.242	0.193
Income (1 if individual income greater than $100,000, 0 otherwise)	0/1	0.040	0.164
Household income (1 if household income between $0 and $19,999, 0 otherwise)	0/1	0.150	0.115
Home ownership (1 if own home, 0 otherwise)	0/1	0.496	0.656
Home ownership (1 if first-time home owner, 0 otherwise)	0/1	0.014	0.437
Home ownership (1 if owned home 2 years or less, 0 otherwise)	0/1	0.667	0.645
Car ownership (1 if household has one car, 0 otherwise)	0/1	0.451	0.399
Car ownership (1 if household has more than two cars, 0 otherwise)	0/1	0.093	0.126
Born in current city (1 if born in city currently residing in, 0 otherwise)	0/1	0.577	0.452
Urban (1 if perceiving to reside in an urban setting, 0 otherwise)	0/1	0.401	0.377
Michigan (1 if residing in Michigan, 0 otherwise)	0/1	0.112	0.153
New Jersey (1 if residing in New Jersey, 0 otherwise)	0/1	0.036	0.082
Ohio (1 if residing in Ohio, 0 otherwise)	0/1	0.335	0.251
Responsible for water bill (1 if responsible for water bill, 0 otherwise)	0/1	0.736	0.880

procedure. Once the surveys had been finalized, survey participants were identified via random sampling by Qualtrics utilizing geographic quotas (Qualtrics 2016). All respondents voluntarily completed the surveys and were at least 18 years of age. Of the 839 surveys from 2013 and the 979 surveys from 2016, 421 and 451 valid responses were received, respectively, providing a 95% confidence (±5% margin of error). To ensure that the sample adequately resembled the sociodemographic conditions sought, researchers used the demographic of income (Table 1). This demographic was selected because shrinking cities characteristically have a high proportion of their populations falling below the poverty level, placing unique challenges on the operating environment of the systems (Faust et al. 2016b). In 2016, poverty rates in shrinking cities were more than double the national poverty rate of 12.7% (Semega et al. 2017). For instance, Detroit, Michigan; Gary, Indiana; and Cleveland, Ohio; had poverty rates of 35.7%, 33.3%, and 35.0% (US Census Bureau 2016).

From each of the 2013 and 2016 surveys, two questions of interest pertaining to stated WTP are modeled:

> How much more would you be willing to pay for improved reliability of your water (wastewater) service? (percent increase in current water [wastewater] bill).

Respondents willing to pay for increased water and wastewater rates could either enter their desired percentage via direct text entry or move a slide bar to their desired value. Opting out of the question did not default to zero and was shown as a nonresponse. With WTP surveys it is common to see respondents report WTP values of zeros, as shown in Fig. 2 (Hensher et al. 2005; Genius et al. 2008; Veronesi et al. 2014; Faust et al. 2018). While these zero values provide information that is important for understanding WTP factors, they may consist of protest zeros. Protest zero responses occur when an individual values the proposed change but holds an aversion to some component of the change, such as the payment mechanism or the entity managing the change. The aversion to any aspect of the program results in so-called protest beliefs in individuals, who respond to WTP questions with a protest zero (Jorgensen and Syme 2000). To avoid the issue of omitted variable bias, the survey tool required respondents to enter 0 if they were not willing to pay for improved water and wastewater LOS reliability. The requirement of entering a 0 made it possible to separate the protested amount (skipping the question) from the entered amount and use it in the statistical analyses (Sudman et al. 1989). In this study, protest zeros are treated as legitimate zeros, because respondents are valuing a policy rather than a commodity (Halstead et al. 1992). Addressing protest zeros is necessary to ensure that neither the true mean WTP is reduced nor that sample selection bias occurs (Halstead et al. 1992; Strazzera et al. 2003; Faust et al. 2015).

The surveys defined LOS reliability as the *perceived* improved quality (e.g., water quality received or reduced combined sewer overflows) or operational characteristics (e.g., fire flows, pressures, reduced disruption of service) associated with the LOS provided. Additionally, open-ended questions ["Do you have any comments or concerns regarding your water (wastewater) service?" and "Do you have any comments or concerns about the water (wastewater) infrastructure system in your city?"] were included in the survey to assess respondents' understanding of their local water infrastructure and service received and used in the discussion throughout.

Surveys, while providing useful information on individuals' perceptions and behaviors, have inherent limitations that pose modeling and interpretation challenges (Faust et al. 2018). Survey instruments do not capture all possible factors influencing an individual's decision or perception regarding certain activities, such as WTP. Thus, many factors, such as lifestyle characteristics, escape observation, potentially giving rise to model specification errors (e.g., omitted variables and erroneous inferences and predictions) (Mannering et al. 2016).

The deployment of the survey to medium and large shrinking US cities may limit the application of the results to this classification of city. Additionally, since the questions of this study focus on public perceptions of WTP for improved water and wastewater LOS reliability, this study only assesses the influence of water sector–related events, such as the Flint water crisis and Superstorm Sandy, as possible explanations for the shift in public perceptions.

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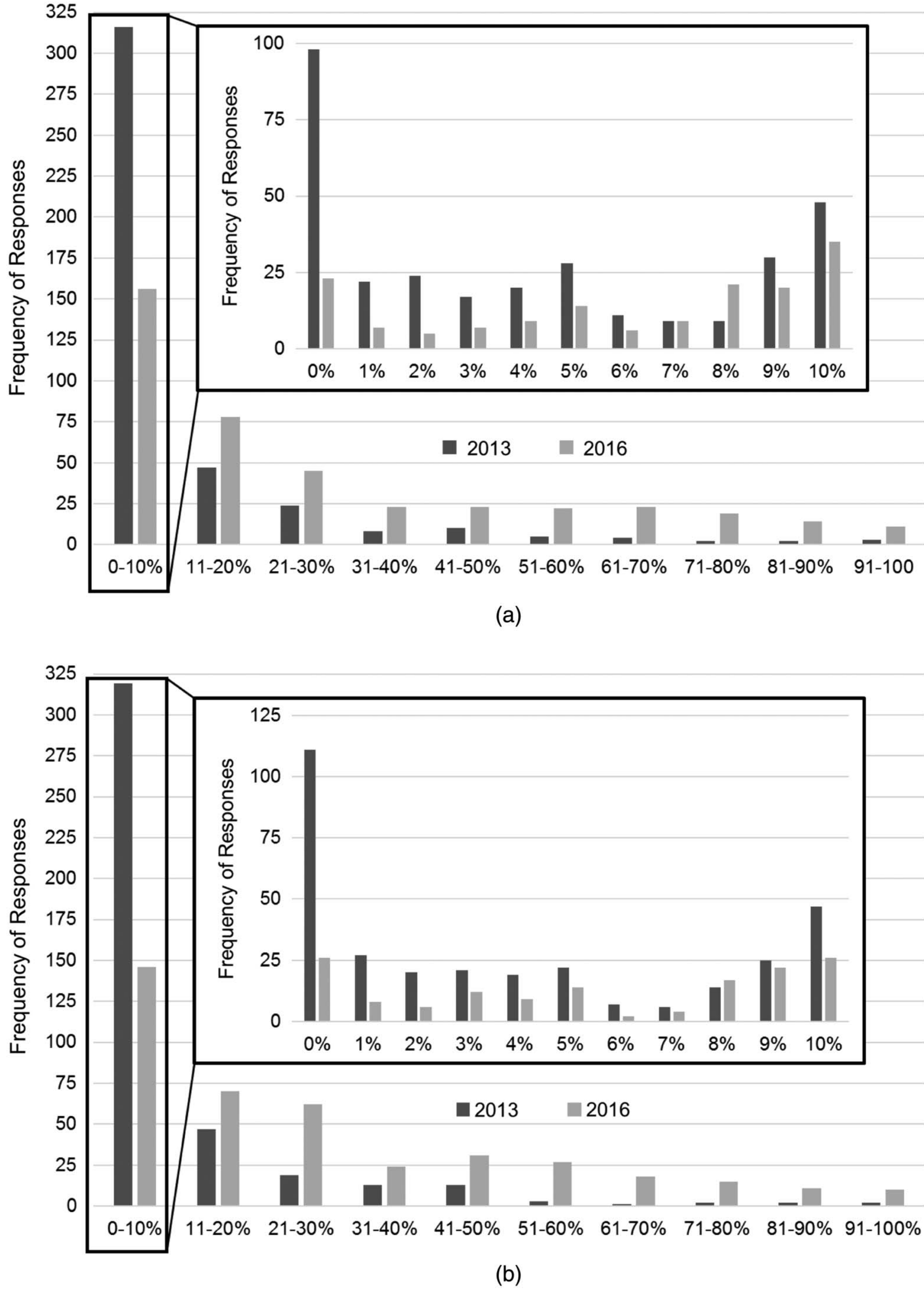

Fig. 2. 2013 and 2016 WTP for improved reliability of (a) water service; and (b) wastewater service.

Other events, such as those not directly related to water-sector infrastructure (e.g., new transportation projects in a city), may have influenced the temporal dynamics of public opinions during this time span and should be considered possible causes. Further, public perceptions regarding water-sector infrastructure may have been altered by events occurring after the 2016 survey and are thus not accounted for in this study.

Econometric Modeling

The Tobit regression modeling approach (Tobin 1958) was selected to account for the high proportion of zero values and potential protest zeros typically found in WTP studies (Faust et al. 2018). By censoring the analysis at a given value, in this case at zero WTP (Fig. 2), Tobit regression can, without omitting observations, account for the skewed nature (distribution) of this data (Faust et al. 2018). The Tobit model alone, however, does not account for any unobserved heterogeneity that innately exists with surveys. As such, heterogeneity-based extensions were applied to ensure accurate parameter estimates and inferences. The random-parameter modeling approach was used, accounting for unobserved heterogeneity by allowing estimated parameters to vary across observations—i.e., individuals in this study—according to a user-defined distribution, such as normal, lognormal, triangular, or uniform distributions, rather than distinct classes (Mannering et al. 2016). This methodology is appropriate for parameters with considerable variation across each observation, such as city-, state-, or regional-level parameters. Notably, past WTP studies applied the latent-class approach to account for this unobserved heterogeneity in WTP survey data. Doing so, however, does not allow parameters to vary within each class, limiting the inclusion of parameters that can vary greatly.

As mentioned, the standard Tobit regression model is able to left-censor data at a value corresponding to the WTP and account for the aggregation of responses at zero (Fig. 2). If traditional linear regression models had been used, the analysis would have ignored this feature of the data set and underestimate the response of WTP to the covariates (Greene 2012). The standard Tobit model is as follows (Tobin 1958):

$$Y_i^* = \boldsymbol{\beta X_i} + \varepsilon_i \quad \text{with } \varepsilon_i \sim N[N, \sigma^2] \quad \text{and} \quad i = 1, 2, \ldots N \tag{1}$$

where

$$Y_i = Y_i^* \quad \text{if } Y_i^* > 0$$
$$Y_i = 0 \quad \text{if } Y_i^* \leq 0$$

where N = number of observations; Y_i = WTP (response parameter) of observation i for improved water or wastewater LOS reliability; X_i = vector of explanatory parameters (geographic and sociodemographic characteristics); β = vector of estimated parameters; and ε_i = normally and independently distributed error term with a mean of zero and constant variance, σ^2. The Tobit regression model is estimated by maximum likelihood estimation procedures [see Greene (2012) and Brown et al. (2015) for more information].

The deployed surveys provide adequate information regarding the sought-after perceptions of WTP for water and wastewater services; however, they are incapable of capturing all possible factors that might influence stated WTP. Ignoring both this unobserved heterogeneity and variation across the parameters leads to inaccurate estimates and erroneous inferences (Mannering et al. 2016). To account for the unobserved heterogeneity, the standard Tobit regression model is extended to incorporate random parameters, allowing estimated parameters within the parameter vector β to vary across observations (Greene 2012):

$$\beta_i = \beta + \phi_i \tag{2}$$

where the log-likelihood function is (Brown et al. 2015)

$$\log L = \sum_{\forall i} ln \int_{\phi_i} g(\phi_i) P(Y_i^* | \phi_i) d\phi_i \tag{3}$$

and $g(\phi_i)$ is the probability density function of ϕ_i and $P(Y_i^* | \phi_i)$ the probability of the Tobit model being censored or uncensored. The probability density function, $g(\phi_i)$, is conditional on a specified distribution—a normal distribution in this study. Because maximum likelihood estimation of the random-parameter method is computationally complex, this study uses Halton draws, a quasi-Monte Carlo simulation–based method to estimate parameter results that has been proven to provide a more efficient distribution of draws for numerical integration than purely random draws (Halton 1960; Train 2000; Bhat 2003).

Parameter and Model Significance

A stepwise procedure [Eqs. (1)–(3)] was used to reveal statistically significant parameters in affecting an individual's stated WTP for improved water and wastewater service reliability. Only parameters that were significant at the 95th percentile were retained for inclusion in the final model. As significant parameters were revealed, two statistical measures were considered in assessing model significance. First, marginal effects were used to interpret model results and determine the impact of an influential driver on an individual's stated WTP. Marginal effects measure the impact of a one-unit increase, when all others are held constant, of an independent parameter on stated WTP values. The marginal effects for indicator parameters—parameters that change from zero to one—are (Greene 2012)

$$\text{Impact} = E[y_i | X_i^1] - E[y_i | X_i^0] \tag{4}$$

where $E[y_i | X_i^1]$ = estimated WTP when indicator variable X_i takes on value 1; and $E[y_i | X_i^0]$ = estimated WTP when indicator variable X_i takes on value 0.

Second, the best-fit model was selected among the fixed and random-parameter Tobit models using the Akaike information criterion (AIC), where the smallest AIC indicated the best models for the data. The AIC is formulated as

$$AIC = -2 \log(\mathcal{L}(\hat{\theta} | data)) + 2K \tag{5}$$

where $\log(\mathcal{L}(\hat{\theta} | data))$ is a maximized log-likelihood function, and K is the asymptotic bias correction term (Burnham and Anderson 2004).

Likelihood Ratio Test

A likelihood ratio test (LRT) was conducted to ensure that the two data sets—i.e., 2013 and 2016 survey data—should be modeled separately and that a statistically significant shift occurred in public perceptions as measured by WTP. To conduct the LRT, a total of three random-parameter Tobit models [Eqs. (1) and (3)] were fitted for WTP for each improved water and wastewater LOS reliability, one model for each individual data set (2013 and 2016), as well as for a combined data set of WTP values from 2013 and 2016. The alternative hypothesis, H_a—that the two surveys are statistically different and should be modeled separately—was tested against the null hypothesis, H_o, that they were statistically similar. The LRT to test the hypothesis (Washington et al. 2010) is

$$\chi^2 = -2[LL_{\beta_T} - LL_{\beta_{2013}} - LL_{\beta_{2016}}] \tag{6}$$

where $LL(\beta_T)$ = log-likelihood at convergence for the model from the combined 2013 and 2016 data sets; $LL(\beta_{2013})$ = log-likelihood at convergence for model using only 2013 data; $LL(\beta_{2016})$ = log-likelihood at convergence for model using only 2016 data; and χ^2 is a chi-square statistic with the degree of freedom being equal to the number of estimated parameters in the combined data set model subtracted from the total parameters in the 2013 and 2016 models.

Results

Survey Results

In 2013, respondents were willing to pay an average increase of 11% for water and 10% for wastewater LOS reliability improvements [Fig. 2(a)]. In 2016 [Fig. 2(b)], respondents were willing to pay an average of 28% for improved water and wastewater LOS reliability, an increase of 17% and 18% from 2013 for water and wastewater, respectively. Responses to the open-ended questions regarding LOS received at the household indicated an understanding of the improved reliability of LOS posed in the WTP questions.

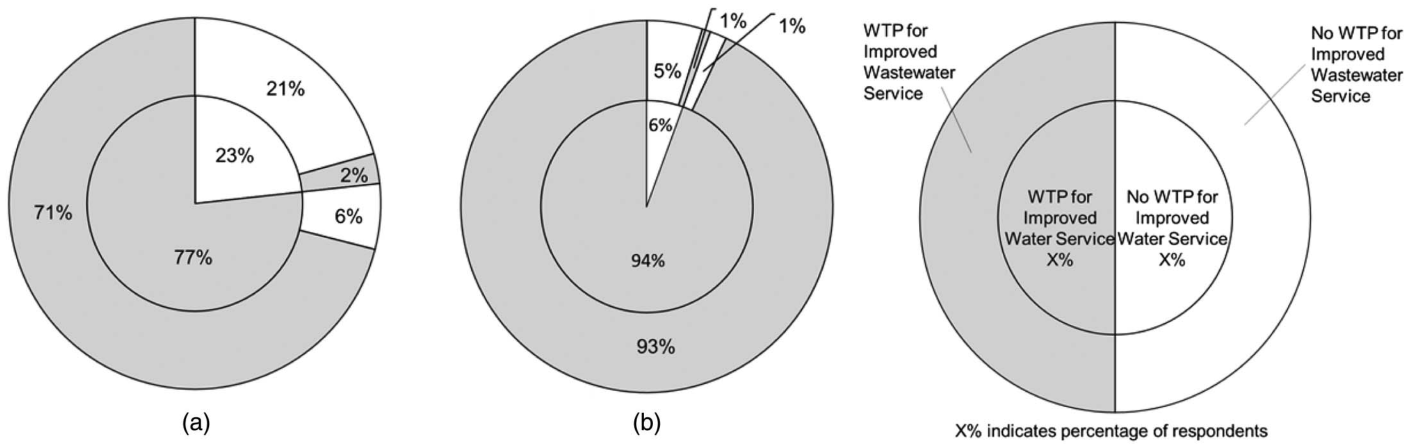

Fig. 3. WTP for water and wastewater improved LOS reliability: (a) 2013; and (b) 2016 (percentage indicates percentage of respondents who are willing or not willing to pay more for LOS improvements).

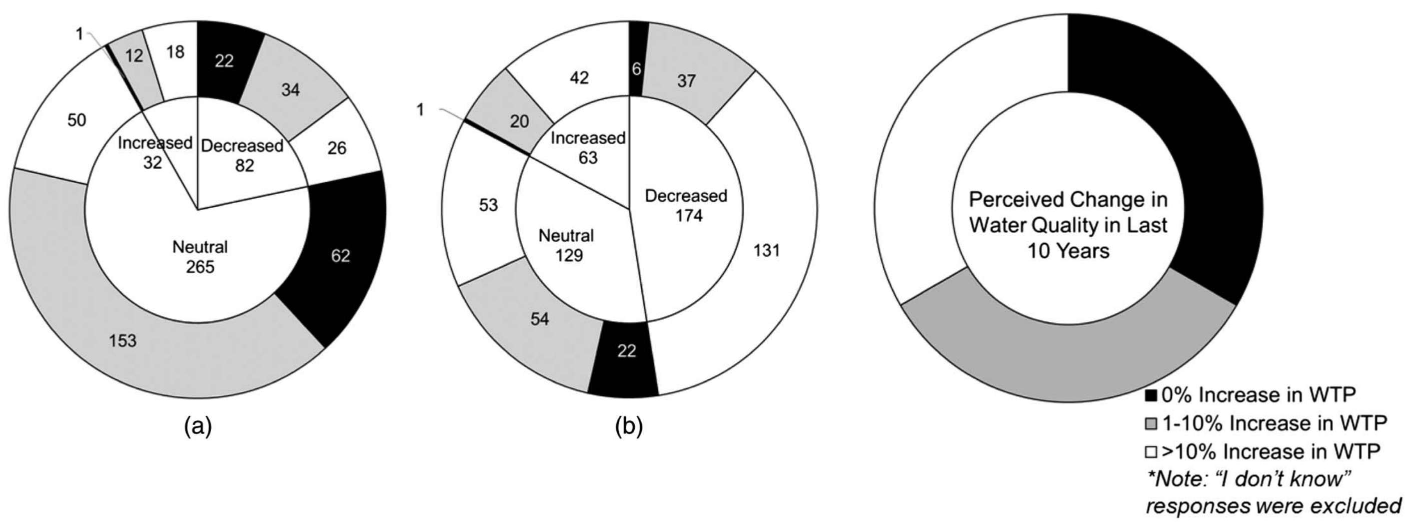

Fig. 4. Perceived change in water quality and respective WTP (i.e., 0%, 1%–10%, >10%) for water LOS reliability improvements: (a) 2013; and (b) 2016.

For instance, "Considering quality and reliability, upgrade is mandatory . . . ," "Recently had to have pipes replaced in front of my house due to breakage . . . ," "I shouldn't have to pay for unclean water . . . ," and "The water mains break frequently . . . " are examples of responses when asked about level of service received.

Fig. 3 explores whether a respondent who is willing—or not willing—to pay more for water LOS reliability improvements would *also* be willing—or not willing—to pay more for wastewater LOS reliability improvements in 2013 [Fig. 3(a)] and 2016 [Fig. 3(b)]. In 2016, 93% of respondents were willing to pay more for both water and wastewater LOS reliability improvements, an increase from 2013 in which 71% of respondents were willing to pay more for both. As shown in the key in Fig. 3, the inner pie chart captures WTP for improved water service, while the outer ring captures WTP for improved wastewater service. For instance, in 2013, 23% of all respondents were not willing to pay more for improved LOS reliability for water. Moving to the outer ring, 21% of respondents across the full sample were not willing to pay more for either water or wastewater, while 2% of the total respondents across the sample were willing to pay more for wastewater but not water for improved LOS reliability.

Fig. 4 shows the relationship between perceived increases/decreases (from 2013 to 2016) in quality of water obtained at the tap and the corresponding WTP. Significant in these figures is the increased number of respondents (i.e., 174 respondents versus 82 respondents) who perceived that their water quality had decreased in the last 10 years from the 2013 survey [Fig. 4(a)] compared to the 2016 survey [Fig. 4(b)]. Attending this increase in perceptions of decreased quality is an increased WTP for improved water LOS reliability (i.e., 60 respondents in 2013 versus 168 respondents in 2016).

Table 1 provides descriptive statistics of significant demographics identified in the 2013 and 2016 models. Select sociodemographic and geographic questions were coded as a binary question, where 1 is indicative of the variable being true for that respondent. The average values shown in Table 1 may be interpreted as the percentage of respondents coded to a particular sociodemographic or geographic group; for instance, an average value of

0.603 for the male variable indicates that 60.3% of survey respondents were male.

Likelihood Ratio Test Results

Through the log-likelihood at convergence values of the final models assessing the WTP for improved water LOS reliability, the LRT, Eq. (6), yielded a χ^2 statistic of 263.12. This χ^2 statistic, with nine degrees of freedom, provides a confidence level exceeding 99.9% that the 2013 and 2016 survey data are statistically different and should be modeled separately. Further, the models assessing the WTP for improved wastewater LOS reliability resulted in a χ^2 statistic of 229.16 and seven degrees of freedom, indicating a confidence level of more than 99.9% that the 2013 and 2016 data should be modeled separately. The results of the LRT verify the temporal dynamic of public perceptions, since between 2013 and 2016 there was in fact a change in the WTP values of residents in shrinking cities for improved water and wastewater LOS reliability.

Table 2. Pearson product moment correlation coefficients for fixed and random-parameter Tobit models

Model	Survey year	Fixed-parameter Tobit model	Random-parameter Tobit model
Water	2013	0.1926	0.9377
	2016	0.1911	0.9952
Wastewater	2013	0.2555	0.9018
	2016	0.1869	0.8697

Random-Parameter Tobit Model Results

As shown in Table 2, the random-parameter approach outperformed the fixed Tobit model for each of the WTPs for improved water and wastewater LOS reliability models as assessed by plotting the actual and predicted stated WTP values and the resultant Pearson product moment correlation coefficients. This finding shows that the random-parameter method captured a significant amount of heterogeneity among the observations and predicted more accurately WTP values than did the traditional Tobit model. Further, this finding validates the use of the random-parameter method in WTP analyses because it was shown to have an effective rate of prediction.

Tables 3 and 4 show the statistically significant parameters found to impact, in 2013 and 2016, the likelihood of an individual's stated WTP for improved water and wastewater LOS reliability improvements. For example, the income parameter, specifically

Table 3. Random-parameter Tobit model results for WTP for improved water LOS reliability

	2013			2016		
Independent parameter	Parameter (t-stat)	Standard deviation (t-stat)	Marginal effect	Parameter (t-stat)	Standard deviation (t-stat)	Marginal effect
Constant	9.166 (6.41)	Fixed		11.721 (10.06)	Fixed	
Male (1 if male, 0 otherwise)	−2.782 (−3.01)	Fixed	−2.338	7.152 (10.00)	15.906 (26.81)	7.152
Age (1 if between 18 and 35, 0 otherwise)	5.931 (5.46)	18.828 (22.18)	4.984	9.549 (13.54)	Fixed	9.548
Marital status (1 if single, 0 otherwise)	−0.633 (−0.63)	5.299 (7.30)	−0.532	—	—	—
Race (1 if white, 0 otherwise)	—	—	—	−10.189 (−12.61)	Fixed	−10.189
Household size (1 if household size greater than two individuals, 0 otherwise)	—	—	—	6.23 (9.14)	14.434 (32.74)	6.232
Education (1 if college degree is highest level of education, 0 otherwise)	—	—	—	−2.136 (−3.16)	8.669 (17.41)	−2.136
Employment (1 if employed or self-employed, 0 otherwise)	—	—	—	5.254 (6.80)	Fixed	5.254
Income (1 if individual income between \$0 and \$19,999, 0 otherwise)	−0.111 (−0.10)	9.556 (11.07)	−0.093	—	—	—
Household income (1 if household income between \$0 and \$19,999, 0 otherwise)	—	—	—	10.181 (9.76)	Fixed	10.180
Home ownership (1 if first time homeowner, 0 otherwise)	—	—	—	5.793 (8.37)	17.277 (34.06)	5.793
Home ownership (1 if owned home 2 years or less, 0 otherwise)	0.919 (0.95)	1.058 (1.91)	0.772	—	—	—
Car ownership (1 if household has one car, 0 otherwise)	2.884 (3.10)	Fixed	2.424	—	—	—
Born in current city (1 if born in city currently residing in, 0 otherwise)	—	—	—	5.447 (7.92)	11.832 (24.47)	5.447
Urban (1 if perceiving to reside in an urban setting, 0 otherwise)	2.688 (2.77)	20.467 (28.81)	2.259	3.966 (5.71)	21.244 (38.77)	3.966
Michigan (1 if residing in Michigan, 0 otherwise)	—	—	—	0.442 (0.48)	17.769 (20.20)	0.442
Ohio (1 if residing in Ohio, 0 otherwise)	−2.519 (−2.56)	4.357 (5.89)	−2.117	—	—	—
Responsible for water bill (1 if responsible, 0 otherwise)	−3.552 (−3.60)	Fixed	−2.985	—	—	—
Log-likelihood at zero		−1,504.42			−1,931.79	
Log-likelihood at convergence		−1,440.76			−1,866.07	
AIC		2,915.50			3,772.10	
Maddala R^2		0.261			0.253	
Number of observations		421			451	

Note: All random parameters are normally distributed.

Table 4. Random-parameter Tobit model results for WTP for improved wastewater LOS reliability

	2013			2016		
Independent parameter	Parameter (t-stat)	Standard deviation (t-stat)	Marginal effect	Parameter (t-stat)	Standard deviation (t-stat)	Marginal effect
Constant	7.467 (5.29)	Fixed		12.990 (4.93)	Fixed	
Male (1 if male, 0 otherwise)	—	—	—	3.704 (2.13)	Fixed	3.518
Age (1 if between 18 and 35, 0 otherwise)	4.384 (3.72)	14.928 (16.74)	3.431	9.451 (5.49)	Fixed	8.976
Race (1 if white, 0 otherwise)	—	—	—	−8.325 (−4.42)	Fixed	−7.906
Race (1 if black, 0 otherwise)	3.822 (2.93)	Fixed	2.991	—	—	—
Household size (1 if single household, 0 otherwise)	−5.020 (−3.62)	Fixed	−3.929	—	—	—
Household size (1 if household size greater than 2 individuals, 0 otherwise)	—	—	—	3.837 (2.28)	8.951 (8.68)	3.644
Education (1 if high school diploma is highest level of education, 0 otherwise)	−2.115 (−1.95)	Fixed	−1.655	—	—	—
Employment (1 if employed or self-employed, 0 otherwise)	—	—	—	4.564 (2.47)	Fixed	4.334
Income (1 if individual income greater than $100,000, 0 otherwise)	—	—	—	6.941 (3.10)	Fixed	6.592
Home ownership (1 if own home, 0 otherwise)	−0.420 (−0.39)	1.906 (2.64)	−0.329	5.793 (8.37)	17.277 (34.06)	5.793
Home ownership (1 if first time homeowner, 0 otherwise)	—	—	—	3.378 (1.98)	12.710 (10.07)	3.208
Car ownership (1 if household has 1 car, 0 otherwise)	4.203 (3.85)	Fixed	3.289	—	—	—
Car ownership (1 if household has more than 2 cars, 0 otherwise)	—	—	—	−10.586 (−3.69)	Fixed	−10.054
Born in current city (1 if born in city currently residing, 0 otherwise)	—	—	—	7.797 (4.62)	7.224 (6.09)	7.405
Urban (1 if perceiving to reside in an urban setting, 0 otherwise)	3.128 (2.79)	20.129 (25.81)	2.448	5.484 (3.22)	20.463 (15.46)	5.209
New Jersey (1 if residing in New Jersey, 0 otherwise)	—	—	—	9.434 (3.21)	14.604 (5.17)	8.960
Ohio (1 if residing in Ohio, 0 otherwise)	−0.343 (−0.31)	5.349 (6.78)	−0.269	—	—	—
Responsible for water bill (1 if responsible, 0 otherwise)	−3.985 (−3.43)	Fixed	−3.119	—	—	—
Log-likelihood at zero		−1,443.31			−1,866.48	
Log-likelihood at convergence		−1,383.82			−1,807.67	
AIC		2,797.80			3,651.30	
Maddala R^2		0.246			0.230	
Number of observations		421			451	

Note: All random parameters are normally distributed.

individuals with incomes between $0 and $19,999, shown in Table 3, had a negative marginal effect in 2013 but was not found to be statistically significant in 2016, indicating a shift in WTP for individuals exhibiting this characteristic. Similarly, in Table 4, the New Jersey state parameter, which was not found to be statistically significant in 2013, was found to have a positive marginal effect in 2016, indicating a WTP for improved wastewater LOS reliability in 2016. Lastly, parameters that were determined to be random (e.g., single marital status in Table 3) are designated with a parameter estimate and a standard deviation. These random parameters indicate that a proportion of respondents who report belonging to a particular sociodemographic or geographic group are either more or less likely to be willing to pay for improved water and wastewater service reliability. In this study, a normal distribution was used. As such, this proportion is determined by plotting the parameter estimate and standard deviation on a normal distribution curve and determining the proportions greater (WTP more likely) or less (WTP less likely) than 0. Notably, although other continuous distributions were considered (e.g., lognormal, triangular, and uniform), the normal distribution was found to provide best overall fit.

Geographic parameters were modeled at the city, state, and regional levels; however, only state-level parameters were revealed as being significant in the models. For instance, Detroit, Saginaw, and Flint were each evaluated as individual city parameters. Michigan, which is an aggregation of Detroit, Saginaw, and Flint responses, was also considered as a potential parameter. Finally, the Midwest was evaluated as a region; it is composed of Indiana, Michigan, Missouri, and Ohio. While select parameters remained consistent—albeit their relative impact may have differed—between 2013 and 2016 (e.g., age and perceiving to reside in an urban area), it can be seen that most differed, reflecting dynamic and temporal perceptions.

Discussion

Model results reveal that between 2013 and 2016 certain geographic and sociodemographic parameters impacted individuals' stated WTP for improved water or wastewater LOS reliability (Tables 3 and 4), supporting the notion that WTP can change over time. Geographic parameters were tested as potential parameters to determine whether there was a statistically significant influence of location on WTP. This influence may be due to local policies, utility relationships, culture, or events that occurred in close proximity. Interestingly, all significant geographic parameters did have water sector–related events occur within or in close proximity to them, supporting this notion of events affecting perceptions [as seen in the literature, such as in Sackett and Botterill (2006), Zielinski-Gutierrez and Hayden (2006), Brody et al. (2008), and Milfont et al. (2014)], and, more specifically, WTP. Notably, the lack of significant city-level parameters may indicate that many of the local issues and challenges may have regional impacts on public perceptions (e.g., Flint water crisis). The impact of proximity to water sector–related events was also evident in the open-ended responses. For instance, respondents stated, "I hear about Flint and lead in Chicago and I am worried," "I am aware that other cities have had significant problems," "I have a lot of concerns about Flint, Michigan's water infrastructure," and "After what happened in Detroit, we need to make sure our water is safe." Specifically, three state parameters, Ohio, Michigan, and New Jersey, were statistically significant in influencing WTP.

Ohio's geographic parameter was found to be significant in 2013, but not 2016 (Table 3). In 2013, approximately 72% of Ohio's shrinking city residents were less likely to be willing to pay for increased water rates, while approximately 28% were more likely. Between 2013 and 2016, water rates in Ohio increased by an average of 3.3%, greater than the national inflation rate (Ohio EPA 2014). The change in consumer price index (CPI)—a measure of the average price of consumer goods—from the previous year was 1.4% and 0.8% in 2013 and 2016 (Ohio EPA 2014). In other words, the cost increase in consumer goods from the previous year was less in 2016 than 2013. This decrease may explain why, in 2013, a majority of residents were less likely to express WTP for increased water rates. This finding supports the idea that public perceptions and WTP can fluctuate, influenced by external events. Hence, gaining a grasp of public sentiment may be done more efficiently with something that goes beyond a single cross-sectional assessment. Indeed, periodic assessments of public opinion and WTP may provide valuable information to decision makers. The periodic accounting of public perceptions could allow for some decisions to stand that may, at another time, have failed. Or, in contrast, decision makers may be able to identify proactive actions that could ameliorate public opposition.

Similarly, the State of Michigan geographic parameter was found to be statistically significant only in the 2016 water WTP model (Table 3). In 2016, slightly more than half (51%) of Michigan shrinking city residents were more likely to be willing to pay for improved water LOS reliability. Michigan was modeled as a random parameter, indicating the heterogeneity of this parameter's impact across the population. Notably, however, on average, respondents were willing to pay increased rates as indicated by a positive average marginal impact. In 2014, as construction was under way for a new pipeline to deliver water from Lake Huron to the city of Flint, Flint sourced its water from the Flint River, resulting in hazardous levels of lead in the public drinking water system, affecting nearly 100,000 Flint residents (CNN Library 2017). As a result, multiple lawsuits, including class action lawsuits, were filed by Flint residents against Michigan, the City of Flint, and several state and city officials. As of March 2018, residents were still being instructed to utilize bottled or filtered water until all lead pipes in the city had been replaced, which, per a court settlement, must be completed by 2020 (CNN Library 2017). The distribution of the two surveys straddled this event, known as the Flint water crisis. Open-ended responses, such as those mentioned previously, support the wide-ranging impact of this event regionally between the time frames of the deployed surveys.

Regarding significant geographic parameters for the wastewater model, the states of New Jersey and Ohio were found to be statistically significant. The Ohio parameter was randomly distributed in the 2013 wastewater model but not significant in the 2016 model. As noted previously, the cost increase in consumer goods in the state of Ohio from the previous year was less in 2016 than in 2013. This decrease may explain why the Ohio parameter was not significant in 2016. Conversely, the New Jersey parameter was not significant in 2013 but was significant in 2016. In late 2012, the aftermath of Superstorm Sandy sent 10 billion gallons of raw sewage into waterways and New Jersey streets (Schwirtz 2013). The storm exposed the faults in the aging wastewater infrastructure and submerged entire sewage plants (EPA 2012). This resulted in millions of dollars in losses, forcing the state senate to act on improving the state's wastewater systems through Senate Bill S-762 in 2016 (217th Legislature 2016). The complete extent of the damage was not reported by the Federal Emergency Management Agency (FEMA) until late 2013, which might explain why the New Jersey parameter was not significant in 2013 but was in 2016 (FEMA 2013). The public's awareness of these happenings in their surroundings might explain the WTP for improved wastewater LOS reliability in New Jersey.

This discussion on significant state-level geographic parameters suggests that public perceptions, as measured by WTP, may indeed be event-driven. Decision makers can present case studies to the public that show that failure to proactively manage infrastructure systems may lead to catastrophic failures. To obtain public support, however, decision makers must not rely solely on the occurrence of external events in their jurisdiction. Decision makers can also continually leverage sociodemographic factors to hamper opposition and sustain or garner public support. For instance, decision makers can gain public support by utilizing the factors that influenced a favorable change in WTP perceptions among certain age groups. By tailoring marketing strategies to these favorable factors, utility managers can help influence public perceptions. Across the final models, various sociodemographic parameters were revealed and as such, are explored in this study.

In all the models, participants who perceived that they resided in a location classified as urban had an increased likelihood of stated WTP for improved water and wastewater LOS reliability. Prior to the shrinking classification, the majority of shrinking cities were large urban metropolises (Pallagst 2009). Prior to their decline, all shrinking cities in this study peaked at approximately 100,000. In 2013 and 2016, however, only 40.1% and 37.7% of respondents perceived themselves to be situated in an urban setting (Table 1). In addition, the results indicate that those born in their residing city were more willing to pay for improved water and wastewater LOS reliability in 2016. This statistic could be capturing individuals with strong place attachment who are often more willing to adapt to changes and are proven to be more willing to engage in public issues (Giuliani 2003; Lewicka 2011). This place attachment is possibly captured in the 2016 model results, which show a decrease from 2013 to 2016 in respondents indicating that they were born in the city where they currently reside (57.7% versus 45.2%).

In both the WTP for improved water and wastewater models, parameters referring to respondents who owned their homes for 2 years or less or who reside in a household with two or more persons were significant in 2016. The finding that a majority of individuals owning a home were more likely to express WTP for improved water and wastewater services suggests an established long-term residency with their city. This is supported by prior research showing that long-term collaborative relationships between utilities and customers lead to heightened trust between the two (Humphries and Wilding 2004). Further, households with two or more persons had an increased likelihood of WTP for improved water and wastewater LOS reliability improvements within shrinking cities. This finding may be capturing dual incomes within the households that contribute to the monthly utility budget. Service bills proportionally impact low incomes more than high incomes (Pallagst 2009; Faust et al. 2016b), therefore respondents with higher total household incomes feel better equipped to shoulder the burden of increased utility rates.

Between 2013 and 2016, respondents between 18 and 35 years of age also had a statistically significant shift in perception regarding stated WTP for improved water and wastewater LOS reliability. Today, younger generations show a greater use of social media and blogs, which are sources of a variety of news and information (Holt et al. 2013; Associated Press 2015; Pew Research Center 2018). This was evident in the survey responses where the percentage of total respondents who indicated that social media was their primary news source was 16% in 2013 and 27% in 2016, as compared to the percentage of respondents between the ages of 18 and 35 who primarily used social media: 29% in 2013 and 61% in 2016 (Table 1). As Bakker and de Vreese (2011) found, when younger populations take advantage of the ease of information accessibility, this often leads to more civic engagement; one result of such participation may be an increase in WTP. The increasing engagement with social media and the ease of information accessibility may explain the positive shift among 18- to 35-year-olds in WTP for improved water and wastewater services. Additionally, engagement in civic activities to cope with community issues increases as more people use social networking as their primary news source (Gil de Zúñiga et al. 2012). As such, utility managers and decision makers may choose to use social media as a platform to convey their messages regarding infrastructure projects and policies to sustain and garner public support.

Studies have shown that residents with lower incomes are willing to pay increased rates for improved water LOS reliability (Knetsch 1990; Whittington et al. 1990; Faust et al. 2016b, 2018). The present study is consistent with that finding, as respondents with lower household incomes (i.e., between $0 and $19,999) were statistically insignificant in the 2013 water model but statistically, and positively, significant in the 2016 model. This shift in perceptions may be capturing a perceived decrease in quality of service within shrinking US cities translating into an increased WTP, as shown in Figs. 4(a and b). This parameter states that even households whose incomes are below the poverty level ($24,563 for a family of four) (US Census Bureau 2016) are willing to pay for improved water LOS reliability in shrinking cities following the perceived decrease in the quality of their water.

In summary, descriptive statistics suggest that, on aggregate, the WTP of residents in shrinking cities changes over time (Figs. 2–4). Cities with limited money and resources for maintenance and capital investment may benefit from using the parameters identified in this study to develop strategies (e.g., outreach programs, targeted education, media advertisements) to target specific sociodemographic or geographic groups. Considering this, utility managers and policymakers can include specific sociodemographic groups and geographic regions in future project planning. This targeted outreach can result in increases to their revenue streams due to shifting perceptions of respondents' stated WTP. Specifically, using the sociodemographic parameters as opportunities for educating portions of communities on the benefits of capital investments as a way of increasing public support for infrastructure projects. Similarly, the use of geographic parameters may also present an opportunity to implement infrastructure projects and increase operational revenue due to higher WTP by residents resulting from a change in the built environment (e.g., events).

Summary and Conclusions

This study sought to assess the temporal dynamics of public perceptions as they relate to stated WTP for improved water and wastewater LOS reliability in 21 shrinking cities in the United States and to investigate the shifts in geographic and sociodemographic parameters that influence this stated WTP. The results of the LRT demonstrate that responses to the 2013 and 2016 WTP questions were statistically different, reflecting a measurable shift that occurred in WTP between 2013 and 2016. Results of the random-parameter Tobit model also indicate that geographic and sociodemographic parameters that influence WTP shifted at some point between when the two surveys were administered. For example, the parameter capturing residents located in shrinking cities in Michigan and New Jersey revealed shifts in stated WTP for improved water (Table 3) and wastewater (Table 4) LOS reliability. Many factors may have contributed to this shift, including proximity of events (e.g., Sackett and Botterill 2006; Zielinski-Gutierrez and Hayden 2006; Brody et al. 2008; Milfont et al. 2014) (the Flint water crisis or aftermath of Superstorm Sandy), new information, place attachment, utility-customer relations, or local economic conditions. Further, increased usage of social media between 2013 and 2016 may have been a factor in the increase in stated WTP for improved water and wastewater LOS reliability among respondents between the ages of 18 and 35 (Tables 3 and 4). Because of this shift in perceptions, the public engagement processes should be continuous and conducted periodically, ensuring that public opinion is being captured adequately. In the example of Portland, had the residents of the city not pursued the infrastructure tax again, they would likely have missed that opportunity for revenue generation (Njus 2016). To reduce the costs of collecting such opinions, it is suggested that public perception data be collected on a regular basis rather than continually or when trying to increase revenues, implement new projects, or integrate new policies. The results of such an analysis can help utility managers and project managers in fiscally strained environments strategize management efforts.

This study, in measuring stated WTP for improved water and wastewater LOS reliability improvements, demonstrates and assesses the temporal nature of public perceptions and introduces the use of the random-parameter Tobit modeling approach to analyzing stated WTP in shrinking cities. These models revealed changing geographic (e.g., state-level) and sociodemographic (e.g., income, age, household size, residential area) drivers of respondents' WTP. Due to the inherent limitations of survey data and WTP studies, the statistical model used in this study accounted for unobserved heterogeneity and protest zeros by allowing estimable parameters to vary across individuals and censoring WTP responses at zero. Notably, the random-parameter approach was found to be superior to the standard Tobit model, indicating that capturing unobserved heterogeneity is necessary to more accurately predict WTP values (Table 2). Further, the results of the random-parameter Tobit model verify that a majority of geographic and sociodemographic parameters affecting WTP perceptions are heterogeneous and vary across the population (Tables 3 and 4). Moreover, respondents' perceived water quality also changed during the 3-year span assessed in this study, likely impacting the WTP (Fig. 4).

Although this study is in the context of shrinking cities, the framework is transferable to cities outside of this classification. For instance, the combination of the deployed survey with Tobit modeling is applicable in assessing WTP in other classifications of cities. Additionally, significant parameters, such as age, household size, and primary news source, found in shrinking cities would be similarly expected to be revealed in other cities; however, we would expect the marginal effects of the significant parameters to differ. Notably, the presence of the income parameter may vary due to the unique operating environment and high poverty levels found in shrinking cities (US Census Bureau 2016). Consistent with previous studies outside of shrinking cities, WTP has been found to increase with respective water quality improvements [cities in Georgia, Jordan and Elnagheeb (1993); four growing Australian cities, Jorgensen and Syme (2000)]. It is important to note that the temporal dynamics of perceptions captured in this study would be expected in other classification of cities with regard to water and wastewater infrastructure as new experiences and proximity to events are not isolated to shrinking cities.

Overall, the findings of this study demonstrate that public perceptions are indeed dynamic, and model results present an opportunity for enhanced collaboration among utility leaders and the public. As noted earlier, surveys cannot capture all possible information about individual perceptions or attitudes. However, decision makers in infrastructure management can deploy future surveys to gather more specific information tailored to their needs and utilize the methods presented in this study to obtain accurate results and interpretations. Continuing to understand the dynamics of public perceptions can create utility management techniques that are feasible for both shrinking and nonshrinking cities, resulting in sustainable infrastructure systems.

Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request. Information about the *Journal*'s data-sharing policy can be found here: http://ascelibrary.org/doi/10.1061/(ASCE)CO.1943-7862.0001263.

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