Leadership in Sustainable Infrastructure
Leadership en Infrastructures Durables

Vancouver, Canada
May 31 – June 3, 2017/ *Mai 31 – Juin 3, 2017*

LOCATIONAL AND DEMOGRAPHIC DRIVERS OF PERCEIVED WATER CONSERVATION EFFORTS IN AUSTIN, TEXAS

Osman, Khalid K.[1] and Faust, Kasey M.[1,2]
[1] University of Texas at Austin, United States
[2] faustk@utexas.edu

Abstract: In Texas, droughts are occurring with increasing frequency and severity. In response, Texas cities have attempted to reduce their water consumption, by imposing water restrictions, having restaurants serve tap water only upon customer request, and incentivizing decreased household consumption. In addition to citywide restrictions (e.g., limiting outdoor water use) many conservation habits have been self-imposed (e.g., using low-flow appliances). This study seeks to assess the drivers leading to perceived conservation efforts in Austin, Texas. In August 2016, a survey was deployed to the general public to understand water use behavior and perceptions of the water infrastructure. Questions pertained to (1) individual water conservation efforts and (2) methods used to conserve water. Survey results from over 400 respondents indicate that 86% of them strive to conserve water. To identify the locational and demographic parameters that increase or decrease the likelihood of one conserving water, this study employs statistical modeling. Modeling the zip codes as locational parameters provides insight into the geographic variability of perceived water use behavior and the identification of possible local influences. Accompanying the statistical analysis is a qualitative analysis of how individuals attempt to conserve water. Study results may inform water providers with influential parameters that are more likely to affect perceived water use behaviors and methods adopted to conserve at the household scale. This information may also facilitate outreach efforts to encourage conservation.

1 INTRODUCTION

The 2011 Texas drought was one of the state's worst ever (Nielsen-Gammon et al., 2012; Acosta-Martinez et al., 2013; Long et al., 2013). City authorities across the state were tasked with responding to the water limitations to meet not just current demands but also future demands. In Austin, officials imposed many citywide water use restrictions. For example, lawns could be watered only one day a week and restaurants served tap water only upon request. Officials encouraged households to adopt various water conservation efforts (e.g., "*Most of these [water conservation efforts]…don't require a major lifestyle shift - just a little change in your normal routine*" [Austin Water Utility, 2017a], *"Customers…can receive rebates and incentives by taking steps to conserve water"* [Austin Water Utility, 2017b]).

How individuals behave with respect to the water infrastructure has been the subject of earlier studies (e.g., McDaniels et al., 1998; Nancarrow et al., 2002; Jones et al., 2011). When this type of study has been carried out in the context of droughts, such as a study by Nieswiadomy (1992), they have focused primarily on addressing the impact of price elasticity on water consumption. Niewswiadomy's research, (1992) conducted in the Western and Southern parts of the United States, demonstrated that when the price of water increased residents were likely to decrease their consumption. Additional studies evaluating water use consumption, although not in a drought context, have assessed the following effects: cost savings due to reduction in consumption (Grafton and Ward, 2008), the impact of environmental policies on perceived residential water consumption (Jones et al., 2011), and the effectiveness of water restrictions on behavioral changes (Grafton and Ward, 2008). Of particular relevance to this study is research carried out by

McDaniels et al. (1998) and Jones et al. (2011). They evaluated how public perceptions of water consumption are driven by such factors as policies and water quality. Jones et al. (2011) highlighted the disconnect (in Greece) between the general public's awareness of the need to conserve water and the decision makers' implementation of water conservation policies. In drought-prone Australia, though, Nancarrow et al. (2002) found that many Australian residents felt a personal responsibility to conserve water, recognizing it as a finite, scarce resource. Kenney et al. (2004) discussed how human-infrastructure interactions differ between mandatory and voluntary restriction periods. In the United States, behavioral changes during droughts were found to be driven by a combination of incentives, restrictions, and the good will of the residents, none of which may hold true during non-drought periods (Kenney et al., 2004).

To indicate how conservational an activity was, McDaniels et al. (1998) analyzed a survey by coding responses to five questions. On a three-point scale, he assigned the response of "never" to one point. A respondent with the highest propensity to conserve water would receive fifteen points. Kenney et al. (2004) utilized regression models to predict the accuracy in measuring perceived water use behaviors relying on r-squared values to explain the findings. Jones et al. (2011) utilized a survey as a means to gauge public perceptions of the water infrastructure by observing the frequency of responses and using multiple ordinal regression models. Using statistical analysis for this type of study further supports survey analysis techniques. If researchers are able to derive marginal effects, they are then able to quantify the different demographic and geographic parameters that contribute to positively or negatively impacting respondent's perceptions. Such quantification allows for further insight into the drivers of perceived water use behaviors. The statistical methods proposed in this study expand on the coding and frequency methods used in previous studies to analyze water use behavior surveys.

This study seeks to further understand human-water infrastructure interactions in the context of perceived water use behaviors in Austin, Texas, which at the time of the survey was in a "conservation stage." During a conservation stage, restrictions are placed on citywide water use. Survey analyses, statistical modeling, and qualitative analyses are used to determine (1) the locational (at the zip-code scale) and demographic parameters (e.g., age, income) that influence individual perceived conservation efforts and (2) how individuals and households are attempting to conserve water. Information provided by this study may be used to support policy changes by water providers, or to construct conservation education programs based on changing the perceived behavior of individuals. Additionally, this study may serve as a framework for gathering this similar information in other communities to inform water providers on perceived, local water conservation behavior.

2 METHODOLOGY

2.1 Survey Deployment

A survey was deployed in August 2016 to the Austin metropolitan area to capture perceptions of personal and household water use as well as of the community's water infrastructure. Prior to deployment, the survey underwent content validation by 10 subject matter experts whose expertise spanned water infrastructure, utility services, public outreach and communications, and survey analyses. The survey was pre-deployed to 15 individuals (not included in the final sample) to ensure the correct data was collected and the questions could be easily understood by individuals with limited knowledge of water infrastructure. Prior to deployment, the survey underwent review by the Institutional Review Board (IRB) at the University of Texas at Austin. All respondents participated voluntarily and were at least 18 years of age. The final sample consisted of 407 valid responses (providing a confidence level of 95% with a margin of error +/- 5%) spanning 29 zip codes. These zip codes crossed three counties (Bastrop, Travis, and Williamson) that were serviced by Austin Water Utility. Survey questions of interest to this study pertained to the following: (1) perceptions of personal water conservation efforts and (2) methods employed to conserve water. Regarding the first topic, respondents were posed a binary question to avoid decision paralysis (Tversky and Shafir, 1992)—either yes, s/he actively attempted to conserve water or no, s/he did not actively attempt to conserve. Regarding the second topic—household water conservation methods—these questions called for open-ended, text responses.

2.2 Binary Probit Model with Random Parameters

In the literature, researchers have used binary probit models to predict individual preference for one of two options in the context of civil infrastructure (e.g., Hausman and Wise, 1978; Faust et al. 2016). Statistical analyses are used to quantify the locational and demographic drivers that increase/decrease the likelihood of perceived water conservation. In Equation 1, P_n (Conserve) represents the likelihood that respondents conserve water for observation n, where Phi (ϕ) is the standardized cumulative normal distribution. Additionally, $\beta_{Conserve}$ is a vector of estimable parameters for outcome *Conserve*, and $X_{Conserve,n}$ is a vector of the observable parameters that determines the outcome for observation n (Washington et al., 2011).

$$[1]\ P_n(\text{Conserve}) = \phi\left(\frac{\beta_{\text{Conserve}} X_{\text{Conserve},n}}{\sigma}\right)$$

To account for unobserved heterogeneity and to allow parameters to vary across the population according to a pre-specified distribution function, a random parameters model is used (Washington et al., 2011). The likelihood of observation n having the outcome of *Conserve* for the random parameters model can be defined as:

$$[2]\ P^{r}_{\text{Conserve}}(n) = \int_x P_n(\text{Conserve}) f(\beta|\varphi)\, d\beta$$

, where $f(\beta|\varphi)d\beta$ is the density function of β and φ is a vector of parameters of that density function (all random parameters are normally distributed in the presented model) (Washington et al., 2011).

2.3 Best-Fit Model Selection

To select the best-fit model for this study, the Aikaike Information Criterion (AIC) was used. The AIC values represent the relative quality of a statistical model given a set of data (Anderson et al., 2000).

2.4 Marginal Effects

Marginal effects were used to measure the average impact of a parameter, given a one-unit change (Washington et al., 2011). In Table 4, a positive marginal effect indicates an increased likelihood of respondents perceiving themselves as conserving water; a negative marginal effect indicates a decreased likelihood of respondents perceiving themselves as conserving water.

2.5 Qualitative Analysis

Responses to *"What methods do you use to conserve water?"* were aggregated into a database for qualitative coding and analysis. The methods for conserving water were coded into three primary categories—Individual Indoor Water Use, Household Indoor Water Use, and Household Outdoor Water Use. Each primary category was subcategorized. For instance, the primary category *Household Indoor Water Use* contained the subcategories *Laundry*, *Kitchen*, *Appliances and Fixtures*, and *Indoor Water*. Some responses were coded to multiple subcategories. For example, "*Shorter showers…run dishwasher less*" was coded to *Bathroom* as well as *Kitchen.* Frequency of responses reflected the total references and number of unique respondents for each category and subcategory, shown in Tables 5-8. Definitions for the primary category and subcategory codes may be found in Tables 1 and 2. Intercoder reliability checks were conducted to validate the coding dictionary and coding (Tinsley and Weiss, 1975; Lombard et al., 2002).

Table 1: Topical codes, primary categories defined

Category	**Definition**

Individual Indoor Water Use	Statements that indicate an *individual* effort to decrease water consumption *inside* the physical household, such as decreasing shower time, shower frequency, or general, intentional decrease in water consumption.
Household Indoor Water Use	Statements that indicate *household* decreases in water consumption *inside* the physical household that may or may not be tasks aggregated among the family members of the household, such as reducing laundry frequency, and upgrading to low-flow shower heads.
Household Outdoor Water Use	Statements that indicate activities which decrease *outdoor* water usage such as shutting off irrigation, xeriscape yards, ceasing to wash cars at home, etc.

Table 2: Topical codes, sub-categories defined

Primary Category	Subcategory	Definition
Individual Indoor Water Use	Intentional Efforts	Statements that indicate a personal commitment to reducing water usage, often stated as "*using less*."
	Bathroom	Statements that indicate a change in bathroom water use behavior, such as reducing shower time and frequency, reducing toilet flushing frequency, and not running tap water while brushing teeth.
Household Indoor Water Use	Laundry	Statements that indicate a change in laundry behavior, such as increasing the laundry load and decreasing the washer time.
	Kitchen	Statements that indicate a change in kitchen water use, such as reducing dishwashing frequency or running dishwasher only when full.
	Appliances and Fixtures	Statements that indicate changes to household appliances and fixtures, such as upgrading to low-flow appliances, shower heads, faucet aerators, and proactive leak prevention in the household.
	Indoor Water Collection	Statements that indicate collecting indoor water for recycling. For example, collecting the water while waiting for shower to warm up, and collecting unfinished water following household meals.
Household Outdoor Water Use	Car Washing	Statements that indicate a decrease in car washing frequency, changes in car washing methods, or ceasing to wash cars at home.
	Outdoor Landscape	Statements that indicate a complete shut off of irrigation, or changes in irrigation scheduling.
	Plants	Statements that indicate the addition of low water plants.
	Misc.	Statements that indicate miscellaneous outdoor water use decreases such as ceasing to fill swimming pool, and ceasing to use power washer.
	Rainwater Collection	Statements that indicate rainwater collection.
	Restriction Adherence	Statements that indicate abiding by city mandated water restriction.

3 RESULTS

The final sample had an average of 14 respondents from each of the 29 zip codes. Table 3 shows select descriptive statistics.

Table 3: Survey sample demographics

Independent Parameter	**Min/Max**	**Ave.**	**St. Dev.**
Male (1 if true, otherwise 0)	0/1	0.62	0.49
Age 18-25 (1 if true, otherwise 0)	0/1	0.10	0.30
Age 26-35 (1 if true, otherwise 0)	0/1	0.32	0.47
Age 36-50 (1 if true, otherwise 0)	0/1	0.23	0.42

Independent Parameter	Min/Max	Ave.	St. Dev.
Age Above 50 (1 if true, otherwise 0)	0/1	0.35	0.48
Employed (1 if true, otherwise 0)	0/1	0.61	0.49
Are you responsible for water bill? (1 if responsible, 0 otherwise)	0/1	0.82	0.38
Household income under $19,999(1 if true, otherwise 0)	0/1	0.04	0.19
Household income between $20,000-$34,999 (1 if true, otherwise 0)	0/1	0.08	0.277
Household income between $34,999 or less (1 if true, otherwise 0)	0/1	0.13	0.34
Household income between $35,000-$49,999 (1 if true, otherwise 0)	0/1	0.12	0.32
Household income between $50,000-$74,999 (1 if true, otherwise 0)	0/1	0.21	0.41
Household income between $75,000-$99,999 (1 if true, otherwise 0)	0/1	0.16	0.37
Household income between $100,000 or more (1 if true, otherwise 0)	0/1	0.38	0.49
Number of cars in household (cars)	0/25	1.93	1.47

Table 4: Model results for the statement *"I actively attempt to conserve water"*

Independent Variable	Parameter (t-statistic)	St. Dev. (t-statistic)	Marginal Effect
Fixed parameters			
Constant	1.551 (6.660)	*fixed*	
Race (1 if African-American, 0 otherwise)	-1.611 (-3.370)	*fixed*	-0.003
Employment status (1 if employed, 0 otherwise)	-0.747 (-2.650)	*fixed*	-0.001
Number of cars in household (1 if more than 3 cars, otherwise 0)	-1.167 (-2.500)	*fixed*	-0.002
ZIP code 78749 (1 if currently residing in ZIP code 78749, 0 otherwise)	-1.930 (-2.780)	*fixed*	-0.003
ZIP code 78739 (1 if currently residing in ZIP code 78739, 0 otherwise)	-1.842 (-2.500)	*fixed*	-0.003
ZIP code 78759 (1 if currently residing in ZIP code 78759, 0 otherwise)	-0.906 (-1.930)	*fixed*	-0.002
Random parameters			
Responsible for water service payment (1 if responsible, 0 otherwise)	3.211 (5.490)	2.864 (6.650)	0.005
ZIP code 78703 (1 if currently residing in ZIP code 78703, 0 otherwise)	-1.615 (-2.070)	2.695 (2.600)	-0.003
Log-likelihood at convergence	*-142.2*		
AIC	*306.3*		
Number of observations	*407*		

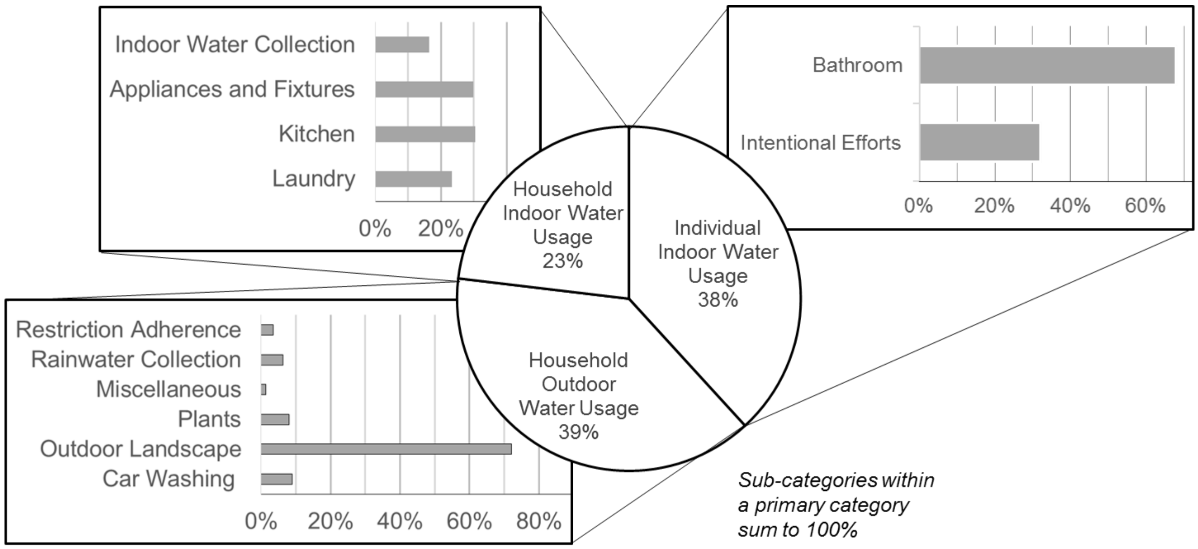

Figure 1: Percentage of reference within each primary category and sub categories for "*What methods do you use to conserve water?"*

Table 5: Topical frequencies of responses to *"What methods do you use to conserve water?"*

	Unique Responses	**Total References**
Individual Indoor Water Use	215	233
Household Indoor Water Use	108	141
Household Outdoor Water Use	195	236

Table 6: Frequency of *Individual Indoor Water Use* codes

	Unique Responses	**Total References**
Individual Indoor Water Use	**215**	**233**
Intentional Efforts	75	75
Bathroom	140	158

Table 7: Frequency of *Household Indoor Water Use* codes

	Unique Responses	**Total References**
Household Indoor Water Use	**108**	**141**
Laundry	33	33
Kitchen	43	43
Appliance and Fixtures	34	42
Indoor Water Collection	21	23

Table 8: Frequency of *Household Outdoor Water Use* codes

	Unique Responses	Total References
Household Outdoor Water Use	**195**	**236**
Car Washing	20	21
Outdoor Landscape	164	170
Plants	17	19
Miscellaneous	2	3
Rainwater Collection	15	15
Restriction Adherence	8	8

4 DISCUSSION

The best-fit model for the statement "*I actively attempt to conserve water*" resulted in significant parameters spanning locational (i.e., zip codes), individual (e.g., employment, water bill responsibility), and household (e.g., car ownership) parameters. The qualitative analysis for the statement, "*How are you attempting to conserve water?*" resulted in three primary categories of water consumption reduction: Individual Indoor Water Use, Household Indoor Water Use, and Household Outdoor Water Use (see Fig. 1).

4.1 Locational Parameters

In influencing the likelihood that respondents perceived they conserved water, four zip codes were statistically significant—78749, 78739, 78759, and 78703. Residents within these four zip codes had a decreased likelihood of perceiving individual water conservation efforts.

Below is a description of the areas represented by these zip codes:

- **78749** is located in Southeast Austin. It is estimated that 67.1% of the homes in this region have three bedrooms or more (ACS, 2015). The median household income for this location is $89,713, which is over three times that of the national household (family of four) poverty rate of $24,339 (US Census, 2016).
- **78739** is located in Southeast Austin. It is estimated that 98.3% of the homes in this region are three bedrooms or greater (ACS, 2015). The median income for this location is $132,026, which is over five times that of the national household poverty rate for a family of four (US Census, 2016).
- **78759** is located in North Austin on the border of Travis and Williamson counties. It is estimated that 44.5% of the homes in this location are three bedrooms or greater (ACS, 2015). The median income for this location is $71,647, nearly three times greater than the national household poverty rate for a family of four (US Census, 2016).
- **78703** is located in Central Austin, concentrated in the downtown area. It is estimated that 40.2% of the homes in this location are three bedrooms or greater (ACS, 2015). The median income for this location is $88,163, which is over three times that of the national household poverty for a family of four (US Census, 2016).

The locational parameters indicated above all that residents residing within these geographic boundaries were less likely to perceive conservation efforts (see Table 4). These locational parameters may possibly be capturing wealth as the four statistically significant locations ranked 1st, 4th, 5th, and 9th for highest median incomes in Austin. All of the locations had average incomes that were greater than the poverty threshold for a family of four ($24,339). Higher incomes are often correlated with larger houses, which require irrigation and contribute to greater water consumption (Willis et al., 2011). This is further supported in that 40% to 98% of households in the areas circumscribed by the four zip codes have three or more bedrooms. These indicators of wealth may be capturing that water bills are not a financial burden to the household. This is consistent with a study conducted in California, which found that low-income households were more than five times as responsive to price increases as compared to wealthy households (Renwick and Archibald, 1998).

4.2 Individual Parameters

As far as influencing the likelihood of respondents perceiving they conserved water, two individual parameters were statistically significant—employment status and being responsible for paying the water bill (see Table 3). Employed individuals were less likely to perceive that they conserved water. Perhaps having a steady salary makes individuals see water rates as being affordable, while being unemployed leads to the opposite view (Faust et al., 2016). Individuals who were responsible for their water bill had an increased likelihood of perceiving that they conserved water. A previous study (Hayes and Cone, 1981) found that in many households the consumption feedback provided by monthly bills decreased daily consumption of infrastructure services (electricity in their study). Australian water utilities found that for many residents comparative water bill data provided on the monthly bill increased the meaningfulness of conserving water (Randolph and Troy, 2008). The dissemination of water consumption data on a comparative month-to-month basis can also lead to increased awareness of household water consumption (Randolph and Troy, 2008). Consistent with previous studies, Austin Water Utility provides monthly, comparative water use data to consumers via water bill for household consumption feedback.

4.3 Household Parameters

The only household parameter found to be statistically significant in the model was that of owning multiple cars. This parameter (i.e., owning three or more cars) decreased the likelihood of perceiving individual water conservation efforts. Howe et al. (2008) discussed that, socio-economic position is determined by not only income but also ownership of vehicles. Thus, this parameter might be an additional indicator of wealth.

4.4 Qualitative Coding

Tables 5-8 identify several important categories of water savings for individuals. Those having the greatest frequency and unique responses were *Outdoor Landscaping* and *Bathroom* codes. Due to the discretionary nature of outdoor water use, it is often the first target for water providers and policy makers to regulate through restrictions (Jorgensen et al., 2009). At the time of the survey, the Austin metropolitan area was in a "conservation stage," thus, aligning with effective management methods found in other studies. What is not so easily regulated is indoor water consumption, which in this study is divided into individual and household indoor water use. Examples of household indoor water use include washing dishes and doing laundry; examples of individual indoor water use include showers, brushing teeth, and flushing the toilet.

Respondents revealed that perceived indoor conservation efforts were often dependant on how an action is performed or the type of technology/appliances in the household. For example, several respondents stated that they "*only wash dishes in the sink.*" Other respondents indicated that they "*use dishwasher only*." Both actions can contribute to using less water (e.g., fully loaded dishwasher, avoid running water during hand washing dishes, etc.). However, different respondents viewed the behaviors differently. Although it is more difficult to regulate indoor water behavior, the responses indicate a willingness to change behaviors. Water providers may use the categories highlighted in Tables 5-8 to inform conservation educational programs about methods currently being adopted (or not) to encourage residential conservation behavior. For example, changes in car washing and laundry habits received a low frequency of responses. Therefore, these may be methods to focus on through outreach campaigns to reduce household water consumption.

5 SUMMARY AND CONCLUSIONS

The increasing frequency and severity of natural disasters (including droughts) give rise to infrastructure service challenges. Regarding water infrastructure service, studies have shown the effectiveness of user awareness and conservation education as methods of decreasing water consumption and changing conservation perceptions (e.g., McDaniels et al., 1998; Kenney et al., 2004; Jones et al., 2011). This study has demonstrated a method to identify the locations and demographics that may be targeted for conservation outreach. Current methods used by providers to reduce water usage, such as fines, can be a financial burden for low-income households (Grafton and Ward, 2008). Therefore, a possible alternative method may be through programs directed at shifting the water use behaviors of residents that are not currently being readily used.

To the author's knowledge, the prior literature has not addressed the specific locational and demographic parameters that lead to higher perceived water conservation behaviors by users. A limitation of this study is that it is a cross-sectional study, capturing perceptions in a single snapshot of time. However, perceptions are dynamic in nature, changing with new information and experiences. Another limitation of the study is that it is only generalizable to Austin, and may not be transferable to other areas.

The statistical analysis performed in this study show that there are several locational and demographic parameters, which affect a resident's perception of water use. Zip codes of wealthier neighborhoods were found to have a decreased likelihood of perceiving water conservation behavior. Additionally, residents who identified as employed were less likely to perceive water conservation behavior. The only statistically significant parameter that increased the likelihood of perceiving water conservation behavior was being responsible for the water bill every month. This is possibly due to the increased water use awareness from feedback provided by the bill. The use of random parameter modeling captured the heterogeneity across the population. Finally, qualitatively analysis found that the most frequent reduction in water use was a decrease in water usage for outdoor landscapes (e.g., irrigation) followed by a decrease in bathroom water usage (e.g., decreasing shower time, decreasing shower frequency, decreasing toilet flushing frequency).

Additional studies should be conducted to assess the possible disconnect between perceived water use and actual water use. A study on perceptions compared to reality could illustrate whether perceiving water conservation reflects decreased water consumption.

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