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Does the urban poor want water service improvement? Residents' preferences for future water service supply in the Central Rift Valley of Ethiopia

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ABSTRACT

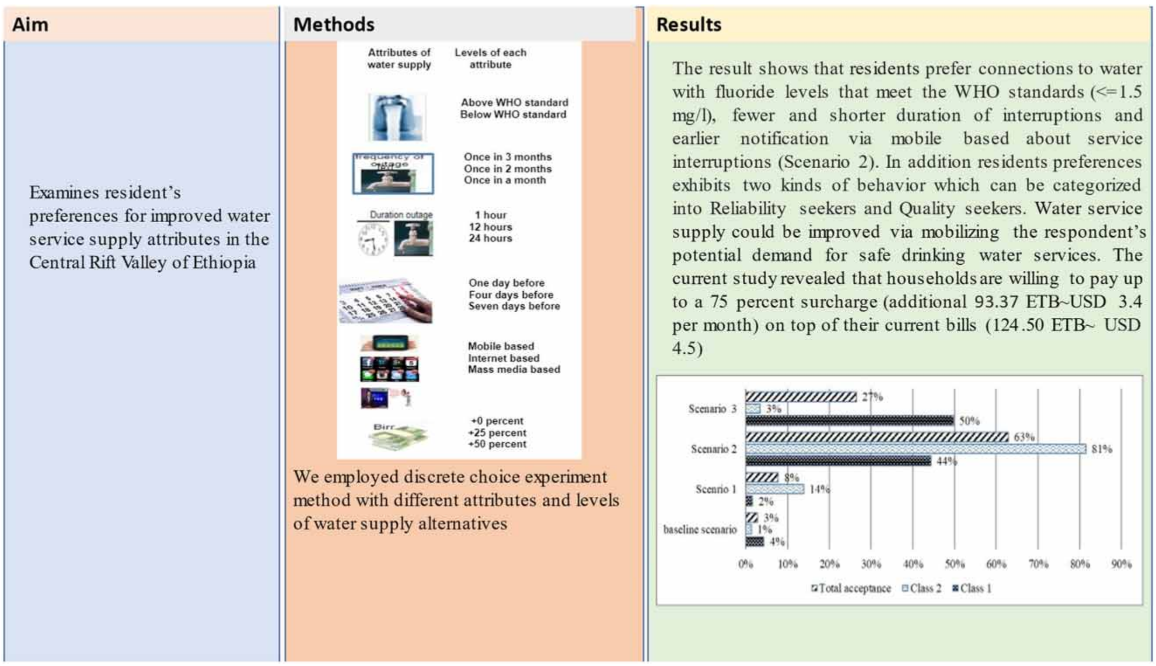
Access to clean and adequate drinking water supply has a significant contribution to public health and the economies of developing nations. However, leaders in developing countries continue to experience challenges in their attempt to provide citizens access to safe drinking water. This study examines residents' preferences for improved water service supply attributes in the Central Rift Valley of Ethiopia. Using a conjoint experiment survey from 450 residents, the study estimates part-worth valuation for each attribute and shows that preference for future water service is heterogeneous. Finally, the researchers confirmed that the resident is willing to pay up to 75% surcharges on their current bill for improved drinking water supply.

Key words: discrete choice experiment, Ethiopia, water supply attribute

HIGHLIGHTS

- Investigate residents' preference for improved water supply in a highly fluoride-concentrated area.
- Applied scenario analysis with simulation based on latent class estimates to come up with the most preferred attributes of water supply.
- New outage information dissemination strategies could improve water supply services.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Access to clean and adequate drinking water is essential for the survival and well-being of human beings. Particularly in developing countries, access to safe water leads to significant public health improvement by reducing waterborne diseases such as cholera, typhoid, and fluorosis. So, by ensuring the supply of clean and adequate water, it is possible to reduce morbidity and mortality rates and the number of working days lost, thereby increasing production and productivity and eventually raising the gross domestic product (Bayrau 2005). One of the 17 Sustainable Development Goals (SDGs) stated for 2030 was (Goal 6) to ensure access to water and sanitation for all. This included the SDG target 6.1 'Proportion of population using safely managed drinking water services'. However, leaders in developing countries continue to experience challenges in their attempt to provide citizens access to safe drinking water (Khan *et al.* 2014; Gunawardena *et al.* 2018). For instance, in Sub-Saharan Africa, only 35% of the urban population has piped water on premises despite the economic (time savings) and public health benefits that household taps offer. About 68% of the Sub-Saharan African population has access to safe drinking water (Adams & Vásquez 2019).

Whereas in Ethiopia, only about 57.5% of the total population has access to safe drinking water, and this number is quite below that of the Sub-Saharan African region (WHO 2015). In addition, in the urban areas of Ethiopia, where there is a relatively better supply of water, the service is often found to be inadequate and unreliable. Besides, the quality of water is inadequate particularly in the Central Rift Valley region where the water has a higher concentration of fluoride. This situation makes urban citizens of Ethiopia in general and people living in the Rift Valley region in particular, vulnerable to health problems and economic marginalization.

Several studies have been conducted on water service demand in the case of both developed and developing countries. Hensher *et al.* (2005), Kwak *et al.* (2013), Lee (2014), Vásquez *et al.* (2009) are some of the scholars who have conducted scientific research works on the demand for water service supply in the developed countries. Similar studies were also conducted in developing countries, particularly in Ethiopia by Bayrau (2005), Huber & Mosler (2013), Hundie & Abdisa (2016), Tarfasa & Brouwer (2013), Lema & Beyene (2012) to mention a few. These studies have investigated households' willingness to pay for improved water service connections in a general context using a contingent valuation method (CVM). However, it is quite important to investigate the value of a safe drinking water supply in the Rift Valley area with excess fluoride concentration. In addition to excess fluoride concentration due to the geological setting, there is also a scarcity of water resources available for the local communities which is one factor that causes a problem of reliable water supply to the community (Bonetto *et al.* 2021). This problem requires enough resource generation to overcome the issues of improved water supply. Thus, attribute-based valuation of water demand helps policymakers to design efficient policies with regard to the improved water supply.

In addition, it helps water supply enterprises in designing improved water supply project financing mechanisms and revenue generation from the residents. In developing countries such as Ethiopia, water suppliers or the government may not afford to improve both the quality and reliability of water supply at a time and hence knowing the resident's preference order and their willingness to help the government design efficient policies that could improve the supply of clean and safe water for residents.

2. BACKGROUND OF THE WATER SUPPLY SITUATION AND AN OVERVIEW OF THE SURVEY AREA

2.1. Overview of the survey area

The Rift Valley region lies between the Ethiopian Plateau to the north and the Somalia Plateau to the south. It has a population of more than 14 million where there is excess fluoride in underground water and which has a clean water supply deficiency. Specifically, the survey area is located in the East Shewa zone covering four woredas such as Adama, Lume, Bora, and Zuway Dugda. These woredas are known as the Central Rift Valley region with the maximum fluoride concentration and low-quality water supply (Figure 1).

2.2. Water supply situation

In Ethiopia, about 14 million people are vulnerable to widespread fluorosis, which is caused by excessive fluoride intake through drinking water (Tekle-Haimanot *et al.* 2006; Entele & Lee 2019). Rango *et al.* (2012) show that there is excess fluoride in underground water surfaces (up to 50 times greater than the World Health Organization (WHO) standards of safe water guideline limit, which is 1.5 mg/l) in the Rift Valley region of Ethiopia. High concentrations of fluoride can cause toxic effects on the human body by damaging mainly

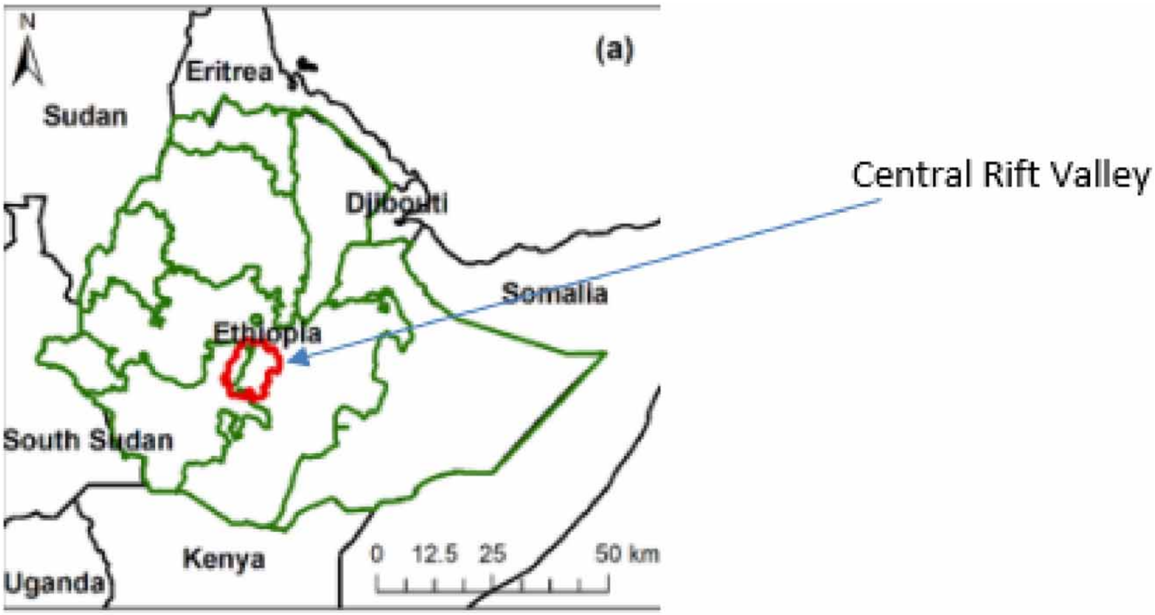


Figure 1 | Map of the Central Rift Valley region.

calcium-containing body parts such as teeth, bones, and the skeletal system (McDonagh *et al.* 2000). In other words, excessive fluoride concentration intake leads to dental and skeletal fluorosis. This in turn results in different psychosocial impacts such as discrimination and social exclusion. According to Sahu & Bansod (2016) and Tekle-Haimanot *et al.* (2006), excessive intake of fluoride has a severe impact on bones, brain, and kidneys. The extent of fluoride intake and its possible impacts on health is summarized in Table 1. Although the fluoride concentration level is very high in the Ethiopia Rift Valley region as a whole, its level varies from place to place. For instance, it varies from 6 mg/l in the Adama area to 202.4 mg/l in Adami Tulu and Jido Kombolcha areas (Entele & Lee 2019). In the area, the water supply is frequently and randomly interrupted and there is no prior information about the blackout. In these areas, some households often resort to alternative sources of improved water supply such as privately investing in water infrastructure and treating water at home. However, the cost of collecting water from alternative sources is significantly higher and less efficient than that of a collectively provided safe tap water system (Whittington *et al.* 1990). For instance, the price per unit of bottled water is typically up to 1,000 times more expensive than tap water (Ferrier 2001). Water treatment at home is also not cost-effective (Goodrich *et al.* 1992). Thus, poor households hardly afford to buy costly bottled water and undertake adequate private investments in water infrastructure and storage facilities.

On the other hand, this study aimed to clarify the demand side preference to connect to the improved water supply. This has several conventional issues including water quality, disconnection frequency, length of blackout, prior notification, means of water service notification, and water tariff level that we examine using the conjoint experiment methodology. Many contingent valuation studies in the past have focused on the primary factors that determine demand. We consider that the water service is composite, with several attributes, and this has an unbundling impact on the preference for each attribute (Lancaster 1966; Hensher *et al.* 2005; Gunatilake &

Table 1 | Fluoride concentration and its effects on the human body

Level of fluoride in mg/l	Effects on the human body
Less than 0.5	Dental caries
From 0.5 to 1.5	No negative effect
From 1.5 to 3.0	Dental fluorosis
From 3 to 10.0	Skeletal fluorosis, i.e., adverse change in bone structure
Greater than 10.0	Crippling skeletal fluorosis and other problems

Source: Sahu & Bansod (2016) and Tekle-Haimanot *et al.* (2006).

Tachiiri 2012; Echenique & Seshagiri 2009; Adams & Vásquez 2019; Ibrahim *et al.* 2020). While there has been little research on people's decision-making relating to the connection to water under various factors, Gunatilake & Tachiiri (2012) adopted the conjoint analysis based on conventional factors in Sri Lanka, Hensher *et al.* (2005) adopted the conjoint analysis in Australia, Adams & Vásquez (2019) adopted choice experiment in Ghana, Ibrahim *et al.* 2020 adopted conjoint experiment in Malaysia, and Vásquez. *et al.* (2022) also used a choice experiment in the Galapagos. Thus, we adopted the conjoint analysis methods and developed the attributes in a more comprehensive manner by considering the actual situation in the Central Rift Valley of Ethiopia. Thus, understanding public preference for improved water supply attributes can help to design appropriate policies for safe drinking water supply.

Based on these grounds, the study aims to answer the following research questions: (1) How much do people value improved water service connection? (2) Is there preference heterogeneity towards quality water services connection? (3) What attributes of water service supply do people prefer? In order to answer these research questions, the study aims to (1) estimate the value of safe water supply with different attribute dimensions; (2) identify the presence of heterogeneity in the preference for future water service attributes; and (3) suggest policy implications on how to improve safe water supply services.

The remainder of this paper is organized as follows. Section 3 presents a literature review on related topics and models. Section 4 describes the methodology of the study, the conjoint survey design for improved water service supply, as well as theoretical models including the Generalized Multinomial Logit (G-MNL) model, and Mixed and Latent Class model. Section 5 presents the results of quantitative analysis for residents' preferences, followed by the simulation results for the hypothetical scenarios of improved water service supply. Section 6 provides concluding remarks, policy implications, and limitations of the study.

3. REVIEW OF THE RELATED LITERATURE

There is a growing body of literature on water demand estimation and household willingness to pay in both developed and developing countries. For instance, Janmaat (2013) investigated residential household water demand, particularly for outdoor water use conservation in the Okanagan Valley in Canada. Dupont (2013) also investigated public acceptance for reclaimed wastewater in order to supplement the water supply during the summer season. According to these studies, the average annual WTP per household ranges from \$142 and \$155. Due to the absence of pre-existing data on household demand for future water service improvements, policy makers mostly depend on stated preference data to understand and estimate public demand (Pattanayak 2006). Table 2 summarizes the literature review of previous studies on demand for water service applying discrete choice methods.

In Ethiopia, there are very few studies conducted on the demand for water service improvement using a discrete choice model such as Tarfasa & Brouwer (2013). However, there are studies conducted by Bayrau (2005) and Lema & Beyene (2012) on the demand for water service. But these researchers used the CVM which does not measure the part-worth values of improved water service attributes. To fill this gap, this study focused on conjoint analysis-based valuation for improved water service supply. The advantage of the conjoint analysis method over the CVM is that it enables which product or service features customers or respondents value over others, and based on that the decision makers can make more informed decisions about the goods/service being valued. Moreover, from a policy point of view, there is merit in seeking to understand households' preferences for several defining attributes of goods and in knowing if and to what extent households consider one attribute more or less important than another (Echenique & Seshagiri 2009). As Lancaster (1966) explained it, 'The consumer obtains the utility from, not the goods per se, rather from the characteristics of the goods'. Therefore, this study uses a conjoint analysis method considering different attributes of future water supply in order to measure residents' part-worth valuation for each attribute of water service improvement.

4. METHODOLOGY

4.1. Survey design and data collection

4.1.1. Conjoint survey

This study used the conjoint method, which enables the use of a stated choice survey of households to measure their preferences in hypothetical situations (Green & Srinivasan 1990; Louviere *et al.* 2000). Stated preference data are usually much richer than revealed preference data and, hence, open up opportunities to enhance the

Table 2 | Discrete choice-based demand for water service studies (SP-stated preference; RP-revealed preference)

Methods and models	Data and country	Main attributes used in the model	Findings/contributions to the literature	Authors
Discrete choice experiment method Mixed logit model.	SP data. 211 respondents. Australia.	Frequency of interruptions/year Duration of interruption/h Notification of interruption Information through call Time of day Price for water service	Households are willing to pay to avoid water interruptions and longer durations. They also prefer weekdays and daytime interruption with low prices.	Hensher *et al.* (2005)
Discrete choice experiment method Conditional logit and mixed logit model.	SP data. 1,800 respondents. Sri Lanka.	Price Quantity Safety and Reliability	Both non-poor and poor households place similar values on water service attributes in terms of hours of supply, safety, and volume but consumption charges are a source of disutility for the poor.	Pattanayak *et al.* (2006)
Discrete choice experiment method. Conditional logit, Nested logit and Mixed logit models.	SP data. 1,000 respondents. UK.	Water supply Water quality Wastewater disposal	Customers placed a high value on minimizing interruptions of water supply along with adequate main pressure.	Willis *et al.* (2005)
Discrete choice experiment method. Conditional logit model.	SP data. 169 respondents. South Africa.	Quantity of water Frequency of water supply Quality of water Price of water Productive use Source of water	Water quality and reliability are more important than the quantity of water delivered. Productive uses of water services are not common in the area whereas there is high demand for domestic use of water.	Kanyoka *et al.* (2008)
Discrete choice method. Conditional logit model.	SP data. 400 respondents. South India.	Quantity Quality Pressure Frequency Summer supply Water supply provider and Cost	There is a demand for water service improvements because 90% of the population in the study area preferred improvements in services with proposed water tariff increments.	Echenique & Seshagiri (2009)
Revealed discrete choice method. Binary logit model.	RP data. 556 respondents. In Tanzania.	Water source Perceived water quality Water collection and Usage practices	Most households preferred boiling first and then using the pot filter system, whereas chlorine additive systems such as siphon filter and PUR had a lower preference.	Burt *et al.* (2017)
Choice experiment method Conditional Logit (CL) and Mixed Logit (ML) models	SP data from 170 respondents in Hawassa city, Ethiopia	Water supply reliability and safety	Households are willing to pay up to 80% extra for improved levels of water supply over and above their current water bill	Tarfasa & Brouwer (2013)
Discrete choice method Conditional Logit (CL) and Mixed Logit (ML) models	SP data in the Galápagos Islands	Improved water services and environmental impacts	Households are willing to pay for water quality improvements, and for the protection of coastal ecosystems and marine organisms. In contrast, households seem indifferent regarding water availability and potential impacts on air quality	Vásquez *et al.* (2022)

(*Continued.*)

Table 2 | Continued

Methods and models	Data and country	Main attributes used in the model	Findings/contributions to the literature	Authors
Discrete choice experiment method Conditional and mixed logit models	SP data in Ghana	Days of service Service hours Water pressure Water quality Connection fees Monthly payment Management	Residents are more sensitive to the time (not day) of service delivery, quality of water, connection fees, and monthly water bills. Households had no preference between a 24-h supply and 12-h supply during the day. Households preferred Accra Metropolitan Assembly (AMA) to Ghana Water Company Limited (GWCL) as the service provider and were willing to pay more for a system managed by AMA	Adams & Vásquez (2019)
Discrete choice experiment method Conditional Logit (CL) and Mixed Logit (ML) models	SP data from 1,200 respondents in Malaysia	Water quality Water pressure, Reduction of water service disruptions	The study discloses that domestic water services are essential to households with less disruption and more quality attributes	Ibrahim *et al.* (2020)

Source: Different literature reviews.

behavioral capability of the Mixed Logit (MIXL) model in situations where market data are scarce, or do not exist in the market (Hensher *et al.* 2005; Jeong 2008).

4.1.2. Sampling and sample size

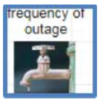
The multistage and mixed sampling strategy was used to choose a representative sample from the target population. In the first stage, the study area was identified as the Rift Valley region where there are problems of excess fluoride with low water service supply, frequent interruption, and long-duration blackouts. In the second stage, the zone and woredas were purposively selected, guided by the regional water supply office's expert in identifying areas with excess fluoride. Then, four woredas were selected, and in each woreda, specific kebeles with excess fluoride and water supply problems were identified. Finally, a list of households from each selected kebele was obtained, and, using systematic random sampling, we have selected 450 sample sizes (which is nearly equal to 6% of the target population of kebeles). A survey questionnaire was distributed to those systematically selected households that have pipeline connections. During questionnaire distribution, a brief explanation of how preference order is filled, meanings of choice alternatives, and their levels were given to selected respondents, so as to enable understand and critically evaluate alternatives and give back an appropriate response. Accordingly, with the help of data collectors, we collected data from 450 residents using a stated choice survey in the study area over two months starting in December 2020.

4.1.3. Attributes and their levels

The first stage of a discrete choice experiment and a conjoint survey involves identifying the attributes relevant to the stated research questions and then assigning levels for each of these attributes (Hensher *et al.* 2005) (Table 3). Accordingly, first, we identified the status quo characteristics of water services in the study area. The water supply has been characterized by high fluoride concentration which is above the WHO standard, frequent interruption of services, long duration of the outage, and absence of prior notification about when and how long water is unavailable (Table 3). We conducted pilot testing to identify the possible difficulties that respondents might face in understanding the survey questions and to make the necessary modifications.

The first attribute (quality of water) describes the concentration level of fluoride in the drinking water in the study area given there is enough pressure when connected. This attribute was captured with two levels, which indicate the concentration level of fluoride in line with the standard limits of WHO. The quality of water supply meets the WHO standard when fluoride concentration is $\leq$1.5 mg/l and it is considered to be below WHO standards when the fluoride concentration is greater than 1.5 mg/l.

Table 3 | Service attributes, levels, and variable definitions

Attribute picture/	Levels	Description	Reasons for these attributes /Status quo
Quality of water supply 	Above WHO standards Below WHO standards	This attribute measures the proposed quality level with reference to WHO standards (maximum 1.5 mg/l).	High fluoride concentration in groundwater
	Once in 3 months Once in 2 months Once in a month	Frequency of water service disconnections per month	Frequent water supply interruption
	1 h 12 h 24 h	Duration of hours for which water is unavailable each time that it goes off (on average)	Long duration of the outage
Length of days for prior notification 	1 day before 4 days before 7 days before	Number of days a notification is received by users prior to service interruption	Random interruptions
Means of notification 	Mobile-based Internet-based Mass media-based	Means of water service notification to customers	No prior notification
Additional value / price/month 	+0% +25% +50%	An additional payment that households are WTP for service improvements per month	

The second attribute (frequency of disconnection) has three levels in the survey design and it is used to capture the number of times residents are willing to tolerate water service disconnection per month. As explained by Hensher *et al.* (2005), interruption of water services may occur for planned maintenance or due to unexpected system failures. The frequency of water service disconnection can be affected by capital investments and the operational capacity of the supplier, with better levels of service generally being attainable through higher costs and hence higher prices. Thus, considering the current water service situation, the survey proposed a frequency of interruptions: once a month, once every two months, and once every three months.

The third attribute (duration of interruption) is important since interruption avoidance is hardly possible because of factors including limitations of financial, environmental, institutional, and technical capacity. However, residents prefer shorter service interruptions to longer disconnections and hence, the attribute has three levels: 1-h duration outage, 12-h duration outage, and 24-h duration of a water service outage.

The fourth attribute (length of days of prior notification) is proposed assuming that before a service interruption occurs, residents need to receive a notification so that they can plan and store water for the number of days that the service will be unavailable (except in the case of emergency interruption when the prior notification is not possible). The number of days required to receive a prior notification may depend on people's workload, work area, type of job, family size, and own sufficient storage capacity. Overall, this attribute is very important in the study area context since the status quo shows random interruption of water services without any notification both pre- and post-interruption. Three levels were used to capture this attribute: 1 day before, 4 days before, and 7 days before the service interruption.

The fifth attribute (means of information service notification) is a variable with three levels – mobile-based, internet-based, and mass media-based service notification. The compatibility of the means of information delivery also matters in the effectiveness of service improvement. For instance, a resident who has no internet connection cannot be notified on internet platforms such as the water provider's website, social media, or email.

The sixth attribute (additional price) has also three levels showing the expected percentage of the additional price that households are willing to pay for service improvements. This attribute is an important variable used to measure the willingness to pay for other attribute levels mentioned earlier. Hensher *et al.* (2005) used price to determine consumer demand for drinking water services and wastewater treatment. In this study, one level for the additional price attribute is 0% (same as the current bill), which is targeted at people who cannot afford to pay for improved water services and may require other means of support for their water service improvement. The second level is plus 25% and the third level is plus 50% of the current bill, all levels being tolerable considering the existing water supply deficiency (in terms of both quantity and quality) and residents' extra spending on averting activities in the study area.

By considering six attributes, five attributes with three levels each and one attribute with two levels, the total choice set for an experiment becomes 486; and we used a fractional factorial design to develop an orthogonal array of a hypothetical future water service package. Using this method, we have ensured maximum efficiency in designing the experiment such as encompassing the principles of level balance, orthogonality, minimal overlap, and utility balance. Finally, we developed an array that contained six choice sets with four alternative services in each set, including the status quo that each respondent had to rate in terms of the likelihood to connect. The sample choice set we designed for households to rank their preferences is shown in Table 4.

4.2. Theoretical models

We have used the theory of random utility (McFadden 1973) as a base for examining consumer preferences using discrete choice methods. The assumption of the model is that respondents choose their preferred alternatives on the basis of their perceived maximum utility. Thus, this study assumes that each resident perceives the utility associated with each attribute of the options of improved water services and chooses the one with the greatest possible perceived utility. In a random utility model, the linear utility function is decomposed into a deterministic component and a stochastic part as:

$$U_{nj} = V_{nj} + \varepsilon_{nj} \tag{1}$$

where subscript n stands for the nth residents and j stands for the jth alternative of a choice situation. U_{nj} is the utility obtained from alternative j by the nth resident. V represents the deterministic utility while ε represents the unobservable utility which captures excluded factors that could affect the utility of an alternative in V_{nj} and factors that are fundamentally unobservable (Ben-Akiva *et al.* 1985). In fact, there are additional models such as the G-MNL (Fiebig *et al.* 2010), which can capture scale heterogeneity; and the Multinomial Logit (MNL) model with a strong assumption (IIA). We have estimated all the models in order to identify and capture preference heterogeneity.

4.3. MIXL model

A MIXL model is used as a highly flexible model to accommodate unobserved heterogeneity in estimation and to approximate any random utility model. It is widely applied in modeling for improved water demand choice using the stated preference method (Whittington *et al.* 1990; Hensher *et al.* 2005). In the MIXL model, unobservable

Table 4 | Sample rank set

Water Services/ alternatives	Quality of water supply (WHO standard)	Frequency of disconnection	Duration of blackout (h)	Length of days prior notification received (days)	Means of notification	Additional price/value	Rank
Alt 1	Below WHO	Once in 3 months	24	7	Mass media	+0%	
Alt 2	Above WHO	Once in 2 months	12	1	Internet	+25%	
Alt 3	Above WHO	Once a month	1	4	Mobile	+50%	
Alt 4	Status quo						

factors can be decomposed into two additive parts ($\varepsilon_n = \eta_n + \delta_n$): stochastic ($\eta_n$), which is correlated over alternatives and heteroscedastic over consumers and alternatives and stochastic part (δ_n), which is IID over alternatives and consumers (Train 2009). Accordingly, the utility of consumer n from choosing alternative j can be defined as:

$$U_{nj} = X_{nj}\beta_n + \varepsilon_{nj} \tag{2}$$

where an unknown parameter β_n which comprises of a vector of coefficients of explanatory variables X_{nj} allows a variation in tests with respect to consumers. To allow the coefficients to vary with respect to consumers in the population, β_n is assumed to have density $f(\beta)$. The choice probability with regard to the random coefficient framework is:

$$P_{nj} = \int L_{nj}(\beta)\, f(\beta)d\,\beta \tag{3}$$

where $f(\beta)$ is the density function and $L_{nj}(\beta)$ is the logit choice probability at parameters β:

$$L_{nj}(\beta) = \frac{e^{V_{nj}(\beta)}}{\sum_{k=1}^{K} e^{V_{nk}(\beta)}}$$

$V_{nj}(\beta)$ is the observed part of the utility. If utility is linear in β, $V_{nj}(\beta)$ becomes $\beta' X_{nj}$ and the choice probability takes the form of (Train 2009):

$$P_{nj} = \int \left(\frac{e^{\beta' X_{nj}}}{\sum_{k=1}^{K} e^{\beta' X_{nk}}} \right) f(\beta)d\beta \tag{4}$$

4.4. Latent Class Logit Model

Although it is important to understand individual preferences as explained in the previous section, sometimes results of individual heterogeneous preferences need to be aggregated based on their similarity group. To meet these needs in this study, we have used the Latent Class Logit Model (LCLM), which assumes discrete mixing distribution where the unobserved heterogeneity is not distributed across individuals but across groups whose behavior is considered homogenous within.

Assume that the entire unit of analysis is categorized into unobservable q classes and individuals belonging to the same class are assumed to have a common preference structure. Based on the random utility theory, we assume that the utility function of individual n belonging to q class for alternative j in choice situation t can be expressed as (McFadden 1974; Greene & Hensher 2003; Woo *et al.* 2017):

$$U_{njt/q} = V_{njt/q} + \varepsilon_{njt/q} \tag{5}$$

where $V_{njt/q}$ is the deterministic part of the utility function, $\varepsilon_{njt/q}$ is a stochastic term which is supposed to follow a type I extreme value distribution, whose probability density is $f(\varepsilon) = e^{-\varepsilon}/(1 + e^{-\varepsilon})^2$ with the cumulative distribution $F(\varepsilon) = 1/(1 + e^{-\varepsilon})$.

As a household decides to maximize its utility, the choice probability for alternative i by household n belonging to class q in choice situation t can be stated (McFadden 1974; Greene & Hensher 2003; Woo *et al.* 2017):

$$\begin{aligned} P_{nt/q}(i) &= P(U_{nit/q} > U_{njt/q}, \forall j \neq i) \\ &= P(V_{nit/q} + \varepsilon_{nit/q} > V_{njt/q} + \varepsilon_{njt/q}, \forall j \neq i) \\ &= \int I(\varepsilon_{njt/q} < V_{nit/q} - V_{njt/q} + \varepsilon_{nit/q}, \forall j \neq i) f(\varepsilon_{nit/q}) d\varepsilon_{nit/q} \\ &= \frac{\exp(X'_{it}\beta_q)}{\sum_{j=1}^{J} \exp(X'_{jt}\beta_q)} \end{aligned} \tag{6}$$

where I (.) is an indicator function equal to 1 when the equation in the parenthesis is true and 0 otherwise. There is a large body of literature that compares the LCLM with the MIXL and the G-MNL models by applying each of them in different domains in empirical studies. However, some studies argue that the selection of a model depends on the researcher's contextual situation. For instance, if a researcher is interested in uncovering individual heterogeneity for identifying decision makers' preferences, the MIXL and the G-MNL models are preferred. However, if a researcher understands that individual behavior ultimately converges into homophile latent groups, thus identifying the heterogeneity of latent groups is important, the Latent Class Model is preferred.

5. RESULTS OF THE STUDY

5.1. Descriptive results

Responses of 450 residents, who have access to pipe water, were used for analysis purposes. Thus, the survey response rate was 100%. The majority of the respondents (67.3%) are male household heads as per the inherited cultural influence in Ethiopia. The households' average income per month was estimated to be 2,505 ETB (Ethiopian Birr) = (92 USD[1]). The average water bill per month in the study area was estimated to be ETB 124.50 (USD 4.5) which is approximately 4.8% of their average income per month. About 52.8% of the respondents have a primary school education, followed by 35.2% of illiterates. Only about 7% are high school (12 Grade) complete and about 5% are diploma and degree holders. The average family size per household was six persons, and the majority of the respondents are farmers, followed by private business owners. Majority of the respondents use the private pipeline as a source of water supply (52.3%) whereas the remaining respondents use the public tap as a source of water supply (47.7%). About 60.8% of the respondents rated the average frequency of water interruption without notification 3 times per month, whereas about 43.5% of respondents rated that the length of disconnection is more than 24 h once interrupted. In addition to this, about 68.2% of the respondents reported that they are using other averting mechanisms to drink improved water. Concerning information notifications related to water services, the majority of households have indicated that they prefer to get notifications via mobile phones followed by local mass media. This result matches the current situation in Ethiopia where mobile phone penetration is relatively higher than internet penetration, which is concentrated only in big towns. Results of this survey also show that the majority of the households (82.1%) prefer mobile-based notifications such as voice calls and SMS.

5.2. Results from the MNL, MIXL, and G-MNL models

We have estimated MNL, MIXL, and G-MNL in order to identify the model which best fits the data. The MIXL model and G-MNL model are those which perform better in fitting the data using the goodness of fit criteria (Pacifico & Yoo 2012). Using the Consistent Akaike Information Criteria (CAIC), Akaike Information Criteria (AIC), and Log Likelihood (LL) the MIXL model is preferred whereas using the Bayes Information Criteria (BIC) the G-MNL model is preferred. To estimate both MIXL and G-MNL, we used the Bayesian procedure with 1980 observations because of some of its advantages in estimation over the classical approach (Manandhar 2012). Following the estimation process used by Train & Sonnier (2003), 10,000 draws with Gibbs sampling were

[1] Exchange rate of Ethiopian Birr to USD was 27.75 ETB = 1 USD in December 2020.

generated by considering burn-in and the draws of every tenth iteration were retained after convergence. The estimated results of the MNL, MIXL, and G-MNLG-MNL are presented in Table 5.

The mean WTP and the relative importance of each attribute are estimated and depicted in Table 6. The value of the marginal WTP result presented in Table 6 backs the discussion made about consumer preferences for future water service attributes. For example, it shows that residents of the Rift Valley region prefer the quality of water that is above WHO standards, and are willing to pay more for improved quality (in terms of WTP, ETB 54.25(USD 1.97)). This was the second most important preferred attribute following price.

With regard to frequency and duration of service interruptions, residents preferred a lesser number of service interruptions and duration of the blackout. In order to measure the degree of preference to avoid frequent and long-time interruptions, we estimated the marginal willingness to pay for each attribute. For instance, residents show that they are WTP about 77.90 ETB (USD 2.83) to avoid a one-time blackout of water service in a month and about 45.38 ETB (USD 1.65) for a 12-h long service interruption.

Table 5 | Estimation results of the MNL, MIXL, and G-MNL models

	Mixed logit (MIXL)				G-MNL		MNL	
	Mean of *B*		Variance of *B*					
Variables	Mean	*t*-value	Variance	*t*-value	Est	*t*-value	Est	*t*-value
Additional price[a]	− 10.67***	−2.58	4.65*	1.88	−12.56***	−2.76	−4.63***	−2.88
Quality Above WHO	1.84***	11.74	2.32***	16.23	1.96***	10.51	0.91***	9.58
Frequency of interruption	−0.14*	−1.81	0.15**	2.29	−0.33**	−2.21	−0.13***	−3.17
Duration of interruption	−1.83***	−4.02	0.59**	2.00	−1.98***	−3.37	−0.24	−1.46
Mobile-based service	0.56***	3.90	0.48***	3.99	0.76***	4.31	0.34***	5.14
Internet-based service	−0.23**	−2.22	0.280**	2.36	−0.58***	−3.21	−0.53***	−7.42
Length of prior notification received	0.31	1.27	0.24***	3.88	0.78*	1.78	−0.16	−1.50
τ (tau)[b]					1.02	1.61		
Γ (gamma)					0.00	0.13		
No. of parameters	14				16		14	
LL	−3,565				−3,567		−3,612	
AIC	3,284.0				4,009.3		4,017.2	
BIC	3,312.7				3,282.5		3,367.8	
CAIC	3,321.4				3,342.1		3,452.3	

[a]The coefficient of additional price is specified to be fixed, so as to facilitate the estimation of distribution of WTP, like Revelt & Train (1998) and Hensher *et al.* (2005).
[b]τ (tau) is the key parameter that indicates if scale heterogeneity is present in the data. As $\tau \rightarrow 0$, G-MNL approaches MIXL. If $\tau > 0$, then G-MNL approaches S-MNL as the diagonal elements of Σ approach zero. If both τ and Σ go to zero, we approach the simple MNL model (Fiebig *et al.* 2010). γ (gamma) is constrained to be between 0 and 1. In extreme cases, $\gamma = 1$ leads to G-MNL-I and $\gamma = 0$ leads to G-MNL-II.
*, **, *** indicate significance levels at 10%, 5%, and 1%, respectively. We have used results of mixed logit model to interpret and discuss the attribute variables.

Table 6 | Mean WTP and relative importance

Variable	Mean WTP	Relative importance (RI_B)
Above WHO	54.25***	16.09%
Frequency per 3 months	−77.90***	0.88%
Duration of disconnection	−45.38***	11.32%
Mobile-based service	70.02***	3.48%
Internet-based service	−87.92***	1.34%
Length of days prior to notification	33.22**	0.66%
Additional price	−	66.23%

Note: *, **, *** indicate significance levels at 10%, 5%, and 1%, respectively.

Related to attributes such as length of prior notification and means of notification, residents preferred longer periods of prior notification and mobile-based notification of the services. For example, the residents are willing to pay for 3 days earlier notification of service interruption on average ETB 33.22(USD 1.21) compared to the status quo (no notification received). In the same fashion, residents have shown willingness to pay for mobile-based service notification of the services on average ETB 70.40 (USD 2.56) compared to other means of notification (internet-based and mass media-based).

This study reveals that households in the Rift Valley region regard additional prices as the most important attribute of water services, followed by the quality of water services above WHO standards. This implies that residents are in need of quality water, which has no excess fluoride concentration at average prices. As explained earlier, the government's water supply policy in both rural and urban areas is targeted at cost recovery. However, the study result shows that residents value lower prices with a higher quality of water services. This shows that there is room for more WTP for improved water service connections.

However, it could be difficult for water provider companies to address each individual preferences to provide water services, especially if the individual preference is heterogeneous. Therefore, considering group-based heterogeneous preferences towards future water services, we estimate the Latent Class Model to observe heterogeneity preference across the groups in this study.

5.3. Results from the LCLM

We used CAIC to select the optimal number of class size and accordingly the optimal number of class size is two (Hole 2008). The estimation result shows that there are two-heterogeneous residents' preference structure for future water service demand. Initially, it had been assumed that regardless of the class, the higher the quality of water services and the lower the price of water, the higher the residents' preferences. However, both Classes (1 and 2) demonstrate opposite sensitivity towards the quality of water services and different magnitudes in the price of water in the latent class estimation results. The estimated results of the LCLM are presented in Table 7.

5.4. Discussion and interpretation

The result of MIXL Model shows that almost all estimated means and their variances, except the mean of the number of days on which prior notification is received, are significant at least at a 10% significance level. Although the longer the number of days when the service notification is received is insignificant, residents' preference with regard to this attribute is heterogeneous as shown from the estimated variance coefficient results.

With regards to water quality attributes, the quality of water above WHO standards is more preferred than the one lower than WHO standards in terms of fluoride concentration. This finding has important clues regarding the fluoride concentration problem, that is, people do not want fluoride in their drinking water. Therefore, this is a call for policymakers and service providers to provide fluoride-safe drinking water continuously as residents' do

Table 7 | Results from the LCLM

	Variables	Coefficient	Std. error	Average MWTP ETB (USD)	Average RI
Class 1	Quality Above WHO	−0.15	0.130	–	6.73%
	Frequency of interruptions per 3 months	−0.18***	0.058	−1.60 (−0.06)	4.18%
	Duration of interruption in hrs.	−0.31***	0.060	−2.69 (−0.099)	42.21%
	Mobile-based service	0.52***	0.090	4.50 (0.16)	10.15%
	Internet-based service	−0.63***	0.080	−5.46 (−0.2)	7.45%
	Number of days prior notification received	0.44***	0.067	3.81 (0.14)	15.62%
	Additional price/month	−0.25**	0.102	–	13.65%
Class 2	Quality above WHO	2.47***	0.384	234.61 (5.8)	74.72%
	Frequency of interruptions per 3 months	−0.12	0.164	–	2.37%
	Duration of interruption in hrs.	−0.01	0.091	–	2.55%
	Mobile-based service	0.49*	0.257	32.10(1.2)	10.22%
	Internet-based service	0.27	0.243	–	5.59%
	Number of days prior notification received	0.02	0.093	–	1.27%
	Additional price/month	−0.16	0.126		3.28%

WTP is not calculated for insignificant coefficients.

***, **, * indicate significance levels at 1%, 5%, and 10%, respectively.

not want to compromise on the quality of their water. Regarding the variances in the estimates, all are statistically significant and the hypothesis of no variances can be rejected justifying the use of MIXL.

Regarding the frequency of service interruptions, the respondents preferred fewer interruptions. The current frequency of interruptions is more than three times per month. Hence, residents are dissatisfied with the existing situation and want service improvement. This result is also consistent with Hensher *et al*. (2005) study in Australia, where consumers were willing to pay significant amounts to reduce interruptions to one time per year.

With regards to the third attribute, 'duration of disconnection', the longer the service interruption, the less utility to the consumers will be. This means that residents' relative utility increases when the duration of service interruption decreases. It is obvious that residents do not necessarily want service interruptions from the very beginning; however, because of capacity limitations and other technical failures, it is difficult to completely avoid interruptions in services. Despite this situation, residents do not still want to have long service interruptions; they want to avoid or decrease the duration of service interruptions.

The fourth attribute is the 'length of day's prior notification received' by residents. Despite the presence of heterogeneity in preference, on average, the longer the prior notification days, the more it is preferred. The presence of heterogeneity might be because of differences in the socioeconomic conditions of the households. Perhaps busy families who are working far away from home may want the notification as early as possible so that they can get time to store enough water. On the other hand, families who are retired, aged, and who stay at home or near home may not want very early notifications as they may forget the notification and fail to store enough water.

When it comes to information communication platforms, we have used three levels defined by dummy variables. Considering the local mass media as a reference means of communication, the MIXL result shows positive marginal utility for mobile-based services such as voice calls or SMS and negative marginal utility for internet-based services such as using web-based, social media platforms, or email compared to the mass media. This finding reveals the real situation in the study context, where many people have adopted mobile services, while access to internet service is very limited.[2] Thus, residents preferred mobile-based service notification compared to the other alternatives.

With regard to price attributes, the coefficient is significant in influencing households' preferences for future water services. The study by Hensher *et al*. (2005) used the share of the current bill, instead of just the proposed price, and found out that it negatively and significantly influenced residents' preferences. Residents preferred quality service at lower prices. From the estimated variance coefficient, we can observe the presence of heterogeneity in preferences that are significant at least at a 10% significance level ($p = 0.10$).

Results from the LCLM reveal two groups of preferences with regard to water supply improvement. Class 1 has more tendency to avoid costs, but it prefers the availability of water services, whereas Class 2 has a tendency to avoid fluoride risk by showing a strong preference for quality of water services above WHO standards (See Table 7).

According to the above results, the first group of residents perceives negative utility but insignificant quality of water services referenced to WHO standards. This shows that people belonging to Group 1 either want to have less fluoride concentration in their drinking water or think the quality of water above WHO standards is unaffordable. This argument is supported by the results of the membership function, which uses the location dummy as a covariate in estimating the LCLM. According to this membership function, *Adama* and *Lume* are areas with less fluoride concentration, and they are relatively low cash crop areas as compared to the other areas considered in the study. However, residents who are in Class 2 value the quality of water services. Therefore, Class 2 residents are those who live in high fluoride concentration areas such as *Bora* and *Zuway Dugda woredas* and those who really want to get rid of the fluoride problem by paying more (the influence of price is not different from zero in Class 2).

Concerning the frequency and duration of interruptions, residents in Class 1 prefer fewer and shorter interruptions whereas those in Class 2 are indifferent. Since the study used the variable 'type of water source connection' (public tap vs. private tap) as another covariate to categorize residents into different groups, the behavior of the two classes can be seen from the perspectives given in Table 7. Such behavior may result from previous experiences that residents in Class 1 more or less get water from the public tap. Such experience may influence their

[2] Mobile penetration rate is 52%, whereas internet penetration is 15.6% (http://www.ethiotelecom.et/).

behavior in such a way that, if water services are frequently interrupted or interrupted for long durations, they think that they do not have other sources of water and hence pay more attention to the availability of water than its quality. Not only do they want less frequency of interruptions and shorter duration of interruptions, but they also want to receive prior notification of services much earlier than the others do.

Regarding the means of information communication platforms, residents in Class 1 strongly prefer mobile-based service notifications, and they strongly dislike internet-based service notifications. This is because mobile penetration is pretty high as compared to internet penetration, and it requires fewer skills to use mobile phones than internet services. This explanation holds true for Class 2 as well, but residents in this class have positive preferences for internet-based services, unlike that of Class 1, although its value is not different from zero.

Sensitivity towards additional prices is different for the two classes. Class 1 has strong sensitivity for the price of future water services, whereas those in Class 2 are indifferent to this, that is, not different from zero. Hence, residents belonging to Class 1 want fewer and shorter interruption times with longer prior notifications for future water services at lower prices, whereas residents in Class 2 want to get quality water above WHO standards, without worrying much about the price of the future water services. Based on this behavior, we can say that Class 1 residents are reliability seekers whereas Class 2 residents are quality seekers.

Among the many variables, only location (level of fluoride concentration) and type of source of water supply were able to significantly differentiate between two different classes of behavior (Table 8). With regards to the relative importance of attributes for each group (Table 7), for Class 1, the duration of water service interruptions, the number of days' prior to notification received, and additional prices are the most important attributes respectively. Frequency of service interruptions and quality of water services above WHO standards are among the least important attributes for Class 1 residents. For Class 2 members, the most important attributes are quality of water services above WHO standards followed by mobile-based service notifications. The least valued attributes are the number of days of prior notification received and the frequency of water service interruptions from bottom up.

5.5. Analysis of simulation results

This section presents a different hypothetical scenario based on the estimation results from the Latent Class Model. We have used class-specific parameter estimates to address the third research objective and question. Considering the existing situation proxies as a base scenario, we have considered three different alternative scenarios in the simulation. According to the class probability model presented in Table 9, the overall sampled population exhibited two types of water demand behavior: Quality seekers and Reliability seekers. Based on this broad behavior, we simulated the cases for each scenario and their acceptance rates.

Based on the proposed improved water supply attribute scenario, we conducted a simulation which is presented in Figure 2. From the scenario analysis for the different alternative cases, it is observed that the quality seekers (Class 2) had a clear preference for the future water service demand. They show that they are clearly aware of the need for fluoride-safe water regardless of the increase in price levels. In addition to fluoride-safe water services, the provision of prior notification for service interruption significantly increased the acceptance rate among Class 2 residents, as it is revealed from Scenario 2 and the overall acceptance rate. However, service availability seekers (Class 1) show their preference in line with the frequency of service interruption and duration of interruption including earlier prior notification, which is captured under Scenario 3. As indicated in Table 9, under Scenario 3, the frequency and duration of interruptions and the number of prior notifications are the best levels among all the scenario levels. Hence, Class 1 residents' preferences are in line with water service

Table 8 | Estimation result for membership function

	Average class probability	Covariates	Coefficient	Std. error
Class 1	0.800	Constants	2.79***	0.81
		Type of water supply connection (public tap or private tap)	2.25**	1.11
		Location (Level of fluoride concentration)	−2.63***	0.97
Class 2	0.200	Reference class		

Note: ***, **, * indicate significance levels at 1%, 5%, and 10%, respectively.

Table 9 | Scenarios of improved water supply

Attributes	Base Scenario (current situation)	Scenario 1	Scenario 2	Scenario 3
Quality of water	Below WHO	Above WHO	Above WHO	Below WHO
Frequency of interruption	More than three times per month	Once per month	Once per month	Once per three months
Length of interruption/h	Longer than 24 h	24 h	24 h	1 h
Means of information communication	No	No	Mobile-based	Internet-based
Number of days of prior notification	No prior notification	No prior notification	7 days earlier	4 days earlier
Additional price per month	+0%	+50%	+75%	+75%

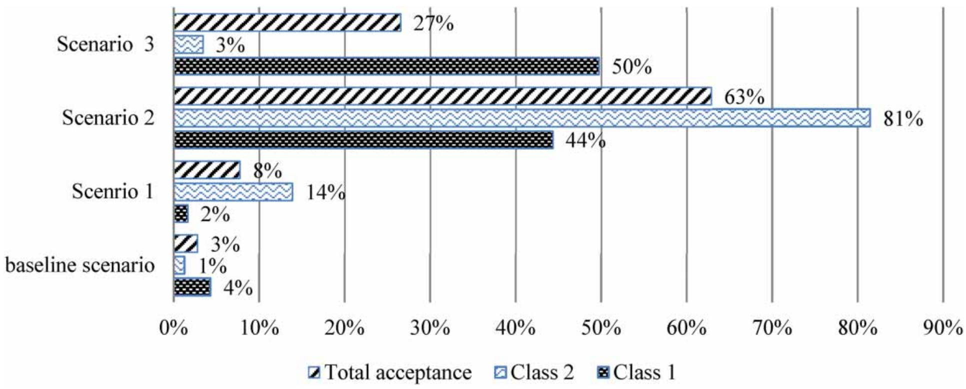


Figure 2 | Simulation results for each scenario and class.

availability regardless of the quality level. In general, improved water supply with prior notification services is the most demanded future water service attribute according to the simulation results in Scenario 2.

6. CONCLUSION AND POLICY IMPLICATIONS

The residents of the Central Rift Valley region in Ethiopia are overexposed to excess fluoride levels resulting in catastrophic health effects such as skeletal and dental fluorosis and damaged brain development. In order to combat this problem efficiently, understanding residents' preference for future water service in the study area is essential for sustainable financing. Accordingly, the current study was aimed at estimating residents' preferences for improved water service supply. In order to realize the stated objectives, the study estimated the G-MNL, MIXL, and LCLMs considering residents' preference heterogeneity. Results from the MIXL model show that residents prefer connections to water with fluoride levels that meet the WHO standards ($\leq$1.5 mg/l), fewer and shorter duration of interruptions, and earlier notification about service interruptions. With regards to the means of water service notifications, the majority of residents prefer mobile-based service notifications compared to mass media-based and internet-based notifications. Additional price was found to be the most important attribute, followed by quality of water service and duration of service interruptions. Therefore, water providers and policymakers should take into account these important attributes of water service supply and look for mechanisms to provide improved water services at an affordable price level.

The result of the LCLM shows that the residents of the Central Rift Valley region exhibit two kinds of behavior which can be categorized into Reliability seekers and Quality seekers. This behavior is based on their experiences and location (whether they had a connection to a private tap or public tap and whether they were living in a high concentration fluoride area or not). Accordingly, one group (or class) of residents seeks the quality of water services (Class 2) whereas the other group looks for the reliability of water services (Class 1). By proposing scenarios, the researcher conducted simulations for each scenario, and the behaviors were clearly observed in the simulation results. Therefore, water providers and policymakers should address fluoride issues first for the people with similar behavior to group two since they prefer water quality that fulfills WHO standards. This group seems to be ready to pay the cost of service improvements since the results show that they are not price-sensitive. On the other hand, for people who have similar behavior to group one, water providers and policymakers should work on minimizing the frequency of water service interruptions and length of interruptions. The overall simulation result shows that there is a higher acceptance rate for an attribute with water quality services meeting WHO standards and with earlier service notification using mobile-based notification (63% total acceptance rate) which is shown by Scenario 2.

The policy implications of this study are targeted at water providers, and the government, as key stakeholders and responsible bodies for improved water supply. Accordingly, the following policy points are suggested:

Water service supply could be improved via mobilizing the respondent's potential demand for safe drinking water services. The current study revealed that households are willing to pay up to a 75% surcharge (additional 93.37 ETB = USD 3.4 per month) on top of their current bills (124.50 ETB = USD 4.5), given they are provided improved water services. However, leadership commitment, availability of sufficient water sources, and evidence-based decision-making practices are among the important issues that determine the implementation of the proposed surcharges and their sustainability. The public trust in water provider companies is also another factor that could affect the implementation of the proposed surcharges.

Another point of suggestion is on improving outage information dissemination strategies. The result of the current study revealed that water providers need to adopt water service notification systems that could enable them to automatically notify residents about service outages. The majority of households prefer to receive notifications through mobile phones (either voice calls or text messages) compared to mass media and the internet. In this regard, our findings are consistent with the findings of previous studies which were conducted using other approaches in Asheville city (USA), North Carolina (USA), New Castle City (UK), Cambridge (USA), and Korea and Lusaka in Africa[3] where water providing companies have an automatic notification system by phone, email, or text message within the affected area.

ETHICAL ISSUES

The author confirmed that the subjects have provided appropriate informed consent with regard to ethical issues.

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DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Adams, E. A. & Vásquez, W. F. 2019 Do the urban poor want household water connections? community preferences and willingness to pay for household taps in Accra, Ghana. *Journal of Environmental Management* **247**, 570–579.

Bayrau, A. 2005 Analyses of affordability and willingness to pay for improved water supply in urban areas of Ethiopia: strategy for full cost recovery. In: *Conference on Management of Water Resources in Ethiopia*, 14–15 May 2004, Addis Ababa, Ethiopia. Institute of Development Research.

Ben-Akiva, M. E., Lerman, S. R. & Lerman, S. R. 1985 *Discrete Choice Analysis: Theory and Application to Travel Demand*, Vol. 9. MIT Press, Cambridge, MA, pp. 715–723.

Bonetto, S. M. R., Caselle, C., De Luca, D. A. & Lasagna, M. 2021 Groundwater resources in the main Ethiopian rift valley: an overview for a sustainable development. *Sustainability* **13** (3), 1347.

Burt, Z., Njee, R. M., Mbatia, Y., Msimbe, V., Brown, J., Clasen, T. F. & Ray, I. 2017 User preferences and willingness to pay for safe drinking water: experimental evidence from rural Tanzania. *Social Science & Medicine* **173**, 63–71.

[3] http://www.lwsc.com.zm/

Dupont, D. P. 2013 Water use restrictions or wastewater recycling? A Canadian willingness to pay study for reclaimed wastewater. *Water Resources and Economics* **1**, 61–74.
Echenique, M. & Seshagiri, R. 2009 Attribute-based willingness to pay for improved water services: a developing country application. *Environment and Planning B: Planning and Design* **36** (3), 384–397.
Entele, B. R. & Lee, J. 2019 Estimation of household willingness to pay for fluoride-free water connection in the Rift Valley Region of Ethiopia: a model study. *Groundwater for Sustainable Development* **10**, 100329.
Ferrier, C. 2001 Bottled water: understanding a social phenomenon. *Ambio* **30** (2), 118–119.
Fiebig, D. G., Keane, M. P., Louviere, J. & Wasi, N. 2010 The generalized multinomial logit model: accounting for scale and coefficient heterogeneity. *Marketing Science* **29** (3), 393–421.
Fiebig, D. G., Keane, M. P., Louviere, J. & Wasi, N. 2010 The generalized multinomial logit model: accounting for scale and coefficient heterogeneity. *Marketing Science* **29** (3), 393–421.
Goodrich, J. A., Adams, J. Q., Lykins Jr., B. W. & Clark, R. M. 1992 Safe drinking water from small systems: treatment options. *Journal-American Water Works Association* **84** (5), 49–55.
Green, P. E. & Srinivasan, V. 1990 Conjoint analysis in marketing: new developments with implications for research and practice. *The Journal of Marketing* **54** (4), 3–19.
Greene, W. H. & Hensher, D. A. 2003 A latent class model for discrete choice analysis: contrasts with mixed logit. *Transportation Research Part B: Methodological* **37** (8), 681–698.
Gunatilake, H. & Tachiiri, M. 2012 *Willingness to pay and inclusive tariff designs for improved water supply services in Khulna, Bangladesh*. Asian Development Bank, Manila.
Gunawardena, A., White, B., Hailu, A., Wijeratne, E. M. S. & Pandit, R. 2018 Policy choice and riverine water quality in developing countries: an integrated hydro-economic modelling approach. *Journal of Environmental Management* **227**, 44–54.
Hensher, D., Shore, N. & Train, K. 2005 Households' willingness to pay for water service attributes. *Environmental and Resource Economics* **32** (4), 509–531.
Hole, A. R. 2008 Modelling heterogeneity in patients' preferences for the attributes of a general practitioner appointment. *Journal of Health Economics* **27** (4), 1078–1094.
Huber, A. C. & Mosler, H. J. 2013 Determining behavioral factors for interventions to increase safe water consumption: a cross-sectional field study in rural Ethiopia. *International Journal of Environmental Health Research* **23** (2), 96–107.
Hundie, S. K. & Abdisa, L. T. 2016 Households' willingness to pay for improved water supply: application of the contingent valuation method; evidence from Jigjiga Town, Ethiopia. *The Romanian Economic Journal* **19** (62), 191–214.
Ibrahim, N. C. S., Kamaludin, M. & Roseliza, M. A. 2020 Dealing with attributes in a discrete choice experiment on valuation of water services in East Peninsular Malaysia. *Utilities Policy* **64**, 101037.
Janmaat, J. J. 2013 Spatial patterns and policy implications for residential water use: an example using Kelowna, British Columbia. *Water Resources and Economics* **1**, 3–19.
Jeong, G. 2008 *Development and Application of Choice Models with Simultaneity and Endogeneity*. PhD Dissertation, Seoul National University, Korea.
Kanyoka, P., Farolfi, S. & Morardet, S. 2008 Households' preferences and willingness to pay for multiple use water services in rural areas of South Africa: an analysis based on choice modelling. *Water SA* **34** (6), 715–723.
Khan, N. I., Brouwer, R. & Yang, H. 2014 Household's willingness to pay for arsenic safe drinking water in Bangladesh. *Journal of Environmental Management* **143**, 151–161.
Kwak, S. Y., Yoo, S. H. & Kim, C. S. 2013 Measuring the willingness to pay for tap water quality improvements: results of a contingent valuation survey in Pusan. *Water* **5** (4), 1638–1652.
Lancaster, K. J. 1966 A new approach to consumer theory. *Journal of Political Economy* **74** (2), 132–157.
Lee, J. S. 2014 Measuring the economic benefits of residential water quality improvement in Ulsan, Korea using a contingent valuation. *Urban Water Journal* **11** (3), 252–259.
Lema, Z. & Beyene, F. 2012 Willingness to pay for improved rural water supply in Goro-Gutu District of eastern Ethiopia: an application of contingent valuation. *Journal of Economics and Sustainable Development* **3** (14), 145–159.
Louviere, J. J., Hensher, D. A. & Swait, J. D. 2000 *Stated Choice Methods: Analysis and Applications*. Cambridge university Press, Cambridge, UK.
Manandhar, S. 2012 *An Empirical Appraisal of Consumer Preferences Toward Internet Adoption: A Discrete Choice Approach. PhD Dissertation*, Seoul National University, South Korea.
McDonagh, M. S., Whiting, P. F., Wilson, P. M., Sutton, A. J., Chestnutt, I., Cooper, J. & Kleijnen, J. 2000 Systematic review of water fluoridation. *Bmj* **321** (7265), 855–859.
McFadden, D. 1973 *Conditional Logit Analysis of Qualitative Choice Behavior.*
McFadden, D. 1974 The measurement of urban travel demand. *Journal of Public Economics* **3** (4), 303–328.
Pacifico, D. & Yoo, H. I. 2012 *lclogit: A Stata Module for Estimating Latent Class Conditional Logit Models via the Expectation-Maximization algorithm*.
Pattanayak, S. 2006 *The Use of Willingness to Pay Experiments: Estimating Demand for Piped Water Connections in Sri Lanka*, Vol. 3818. World Bank Publications.
Pattanayak, S. K., Mansfield, C., van den Berg, C., Johnson, F. R., Yang, J. C. & Jones, K. 2006 *Unpackaging demand for water service quality: Evidence from conjoint surveys in Sri Lanka*. World Bank Policy Research Working Paper, 3817.

Rango, T., Kravchenko, J., Atlaw, B., McCornick, P. G., Jeuland, M., Merola, B. & Vengosh, A. 2012 Groundwater quality and its health impact: an assessment of dental fluorosis in rural inhabitants of the Main Ethiopian Rift. *Environment International* **43**, 37–47.

Revelt, D. & Train, K. 1998 Mixed logit with repeated choices: households' choices of appliance efficiency level. *Review of Economics and Statistics* **80** (4), 647–657.

Sahu, N. & Bansod, B. K. 2016 Detection of fluoride ion in water: an optical approach and review. *vol*, *5*, 347–358. India 2016.

Tarfasa, S. & Brouwer, R. 2013 Estimation of the public benefits of urban water supply improvements in Ethiopia: a choice experiment. *Applied Economics* **45** (9), 1099–1108.

Tekle-Haimanot, R., Melaku, Z., Kloos, H., Reimann, C., Fantaye, W., Zerihun, L. & Bjorvatn, K. 2006 The geographic distribution of fluoride in surface and groundwater in Ethiopia with an emphasis on the Rift Valley. *Science of the Total Environment* **367** (1), 182–190.

Train, K. E. 2009 *Discrete Choice Methods with Simulation*. Cambridge University Press, New York, NY.

Train, K., Sonnier, G., 2003 Mixed logit with bounded distributions of partworths. In: *Applications of Simulation Methods in Environmental Resource Economics* (Alberini, A. & Scarpa, R., eds). Kluwer Academic, New York.

Vásquez, W. F., Mozumder, P., Hernández-Arce, J. & Berrens, R. P. 2009 Willingness to pay for safe drinking water: evidence from Parral, Mexico. *Journal of Environmental Management* **90** (11), 3391–3400.

Vásquez, W. F., Raheem, N., Quiroga, D. & Ochoa-Herrera, V. 2022 Valuing improved water services and negative environmental externalities from seawater desalination technology: A choice experiment from the Galápagos. *Journal of Environmental Management* **304**, 114204.

Whittington, D., Briscoe, J., Mu, X. & Barron, W. 1990 Estimating the willingness to pay for water services in developing countries: a case study of the use of contingent valuation surveys in southern Haiti. *Economic Development and Cultural Change* **38** (2), 293–311.

Willis, K. G., Scarpa, R. & Acutt, M. 2005 Assessing water company customer preferences and willingness to pay for service improvements: a stated choice analysis. *Water Resources Research* **41** (2), 2–8.

Woo, J., Jang, J., Moon, H. & Lee, J. 2017 Analyzing public preference and willingness to pay for spent nuclear fuel facilities in South Korea: a latent class approach. *Progress in Nuclear Energy* **100**, 255–265.

World Health Organization, WHO/UNICEF Joint Water Supply, & Sanitation Monitoring Programme 2015 *Progress on Sanitation and Drinking Water: 2015 Update and MDG Assessment*. World Health Organization, Geneva.

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