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Willingness to pay for improved safe drinking water in a coastal urban area in Bangladesh

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Abstract

Discontentment with a piped supply system of drinking water has become a significant concern in Bangladesh's urban areas in recent years, necessitating the improvement of different aspects of the system in question. Therefore, by conducting a discrete choice experiment on 115 households out of a systematically selected 161 households, this study aims to estimate the willingness to pay (WTP) for an improved safe drinking water supply by considering the trade-offs made by urban dwellers for the proposed improvements to an existing water supply system in the Khulna City Corporation (KCC) area of Bangladesh. The primary results show that the total WTP of households is estimated at BDT 243.6 (≈US$ 2.87) per month, implying that respondents are ready to pay for improvements to the water supply attributes of water quality, regularity of supply, water pressure in taps, and filtering. A revenue stream for an improved water supply system is also being developed, suggesting that investment in improving the system would be a 'no-regret' decision and economically sustainable.

Keywords: Bangladesh; Choice experiment; KWASA; Safe drinking water; Willingness to pay

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Highlights

- This study presents the estimation of willingness to pay (WTP) for pure drinking water supply in a coastal urban area in Bangladesh.
- This study deployed a choice experiment method to estimate urban dwellers' WTP for safe drinking water supply.
- We also present a revenue stream of supplying pure drinking water denoting that investment in supply system development would be a 'no-regret' decision.

Introduction

Globally, 785 million people do not have access to safe drinking water, while nearly two billion others can only access a drinking water source contaminated with faeces (WHO, 2019). This scenario is acute in the urban areas of developing countries due to a higher degree of population density, in-migration, and economic activities (Buhaug & Urdal, 2013). To mitigate these challenges, the Sustainable Development Goals (SDG 6 and 11) have proposed a reasonable solution for water stress issues in urban areas; however, water safety still appears to be a fundamental concern in developing countries (Vásquez *et al.*, 2009; Wang *et al.*, 2018). Water safety can be delineated by incorporating several attributes such as water quality, pressure, timing, and cost (Wang *et al.*, 2014). To possess these attributes, the water source needs to be located inside a dwelling, yard, or plot via a piped water supply (UNICEF and WHO, 2017). In many developing countries, a key hurdle to extending and providing a piped water supply is the cost to the consumer (Kayaga *et al.*, 2018). Given this context, almost 1.8 million people die every year in developing countries from water-borne diseases such as diarrhoea and cholera due to drinking unsafe water (WHO, 2015). Access to safe drinking water improves human health by diminishing the mortality rate from such water-borne diseases. Empirical evidence suggests that within 30 years, Brazil made a welfare gain of US$ 7,500 per capita by improving access to safe drinking water for the mass population. Similarly, in Argentina, child mortality dropped by 8% because of the expansion of a pipeline water supply and water quality improvement (Soares *et al.*, 2008). However, developing countries are struggling to ensure a consistent supply of safe drinking water, which would reduce mortality and infectious disease rates.

In Bangladesh's urban areas, the supply of piped drinking water services is frequently interrupted (Gomes *et al.*, 2018). Furthermore, piped water is likely to be contaminated due to inadequate treatment and testing, making it unsafe to drink. As a result, households incur additional expenditure through storing and treating (e.g. boiling) the supplied water before they drink it. Some evidence suggests that the degree of water quality has an influential impact on people's inclination to pay, though this depends on their awareness and income level. In this regard, the existing supply source of water, perceived benefits, water charges, productive activities, literacy level, household characteristics, disease history, and credibility of the supplying authority significantly affect people's willingness to pay (WTP) for access to safe drinking water (Chatterjee *et al.*, 2017). This strongly suggests that households' preferences for improved water supply services should be assessed, especially their WTP for certain levels of supply services. In developing countries like Bangladesh, before imposing any tariff for an improved water supply service, it is essential to estimate people's WTP as determined by their socioeconomic characteristics; these characteristics will differ between, for instance, the dwellers of Dhaka in Bangladesh and the residents of Jacksonville in the USA because of the contextual differences (Gunatilake & Tachiri, 2014; Chatterjee *et al.*, 2017). Furthermore, due to global climate change impacts, urban areas suffer from multifarious water stresses, resulting in acute scarcity of safe drinking water in daily life for their inhabitants (Wutich, 2020).

Due to the adverse impact of climate change, Bangladesh suffers from a significant drinking water scarcity, which is worsening day by day at present (Islam *et al.*, 2019; Nahin *et al.*, 2020). Forecasts from previous studies suggest that, along with other developing countries, Bangladesh is likely to experience substantial water stress by the year 2025 (Chowdhury, 2013). In recent years, three specific factors appear to have affected the scarcity of drinking water in the south-western region of Bangladesh: (a) deepening of groundwater level, (b) salinity intrusion, and (3) arsenic contamination (Karim & Safiuddin, 2003; Rabbani *et al.*, 2013). Most people in urban Bangladesh depend on groundwater for fulfilling their daily water needs. However, significant arsenic contamination in groundwater is forcing people to collect drinking water from shallow tube wells instead (Karim & Safiuddin, 2003). Furthermore, salinity in groundwater in the south-western region is reducing people's access to healthy and safe drinking water (Nahin *et al.*, 2020). Presently, Bangladeshi urban areas are encountering significant in-migration from rural areas, which creates enormous challenges for urban lifelines, especially as the pressure of additional urban immigrants makes the water supply crisis more complex. It appears that this crisis will be enhanced by the gradual depletion of groundwater level in the coming years, creating an acute scarcity of safe drinking water.

Given the expected water scarcity scenario, Bangladesh's government has possible remedies for overcoming this problem in major urban cities. The Water Supply and Sewerage Authority (WASA) branches in various cities are implementing projects to ensure an uninterrupted supply of safe drinking water for city-dwellers (Chowdhury, 2013). For instance, Khulna Water Supply and Sewerage Authority (KWASA) recently initiated a project to ensure the supply of safe drinking water to Khulna residents, although only 22% of city-dwellers will enjoy the benefit from this project (KWASA, 2019). Although the project has been well-planned, KWASA seems to be ignoring the inherent cost of offering water supply services at optimal standards. For example, assessing and estimating city-dwellers' WTP for an improved safe drinking water supply is a critical issue that is yet to be investigated. Such an estimation could be a crucial tool for determining water prices, as it would allow concerned agencies such as KWASA to operate their water supply systems efficiently and without interruption. However, very little empirical research has determined city-dwellers' WTP for improved safe drinking water in Bangladesh (see Gunatilake & Tachiri, 2014) where no water supply attribute is considered. Recent notable studies have broadly focused on consumers' perspective, i.e. demand-side (Vásquez *et al.*, 2009), while Wang *et al.* (2018) considered both consumers' (demand-side) and producers' (supply-side) perspectives when estimating WTP for a pure drinking water supply. However, none of these studies has considered the investment prospect of a drinking water supply for the agencies concerned. Thus, this study attempts to estimate households' WTP for an improved safe drinking water supply by KWASA in the Khulna City Corporation (KCC) area; to do so, the study applies a choice experiment (CE) method and considers different water supply attributes. Furthermore, it proposes an investment prospect for KWASA's water supply project. To the authors' best knowledge, this study is the first attempt to estimate economic benefit (in terms of WTP) for an improved water supply system in the KCC area by utilizing a CE approach.

Materials and methods

There are two approaches – stated preference and revealed preference – that are widely accepted methods in the literature for valuing an environmental good. The choice between these two competing approaches largely depends on the way that the research objectives are addressed. When computing the value of an improvement in the non-market environment good under hypothetical schemes, the stated preference approach (i.e. direct WTP elicitation for the use-value of the proposed improvement) has advantages over the revealed preference approach (i.e. indirect WTP computation for an improvement in order to minimize the negative externality), as suggested by the empirical findings of a recent study by Ahsan *et al.* (2020). As this study attempts to estimate WTP for some hypothetical improvement in the KWASA supply system, we used the stated preference approach in order to value attribute-specific improvement. Furthermore, we prepared a prospective revenue generation stream for two and a half decades, applying the approach used by Ahsan *et al.* (2020).

The stated preference approach includes two more distinct methods. CE is usually used to point out each respondent's preference through a set of attribute-specific improvement combinations accompanied by the price from alternative sets of combinations. On the other hand, the second method, contingent valuation (CV), offers the respondent the opportunity to express his/her maximum WTP for a predetermined/proposed improvement in the environmental good/service. The CE method is more holistic and exhaustive than the CV method in revealing respondents' proper preference among alternative improvement plans. Furthermore, the CE method provides a more efficient 'welfare gain' than the CV method when dealing with non-market goods and/or services (Mogas *et al.*, 2002). Thus, as the area of study is an urban context in a developing country, this study applied the CE framework, which is nowadays widely used for estimating WTP for environmental goods and/or services. Within this framework, conditional logit (CL) models were once predominant in estimating attribute-specific WTP. However, CL has some shortcomings in terms of estimating WTP precisely, which may produce biased results. Considering the challenge in question, this study applied mixed logit (ML) models to compute the total WTP for proposed improvement and reported the CL estimates of Kouser & Qaim (2013).

In this study, we first used standard CL and ML (without alternative specific constant (ASC)) models. Then, we incorporated the ASC variable in both sets of standard models. Finally, some interaction variables were included in the ASC-included standard models. These models were used to compute respondents' attribute-specific marginal willingness to pay (MWTP) for an additional unit of improvement in each attribute (Dauda *et al.*, 2015). However, this study used MWTP estimates from ML models to compute the total WTP in order to minimize model-induced biases. Later, the total WTP estimate was used for the second research objective, i.e. the present value of future revenue streams from this project using the discounting approach (see Figure 1).

Experimental design

The justification for using the CE framework in this study to estimate respondents' WTP for improved drinking water supply systems is set out in the Supplementary Appendix. A typical CE framework consists of four steps. The first and most crucial step is to select the attributes in which improvement is required. The second step is to design the choice cards with levels and values. The third and fourth steps include questionnaire designing and the sampling strategy.

Attribute selection. Attribute selection is one of the most crucial parts of designing a CE framework since the difference in attribute selection might result in significantly different WTP estimates. Hence, a set of relevant attributes was selected through an in-depth literature review; these potential attributes were then shared with five local water experts (a city corporation officer, local consultant, KWASA

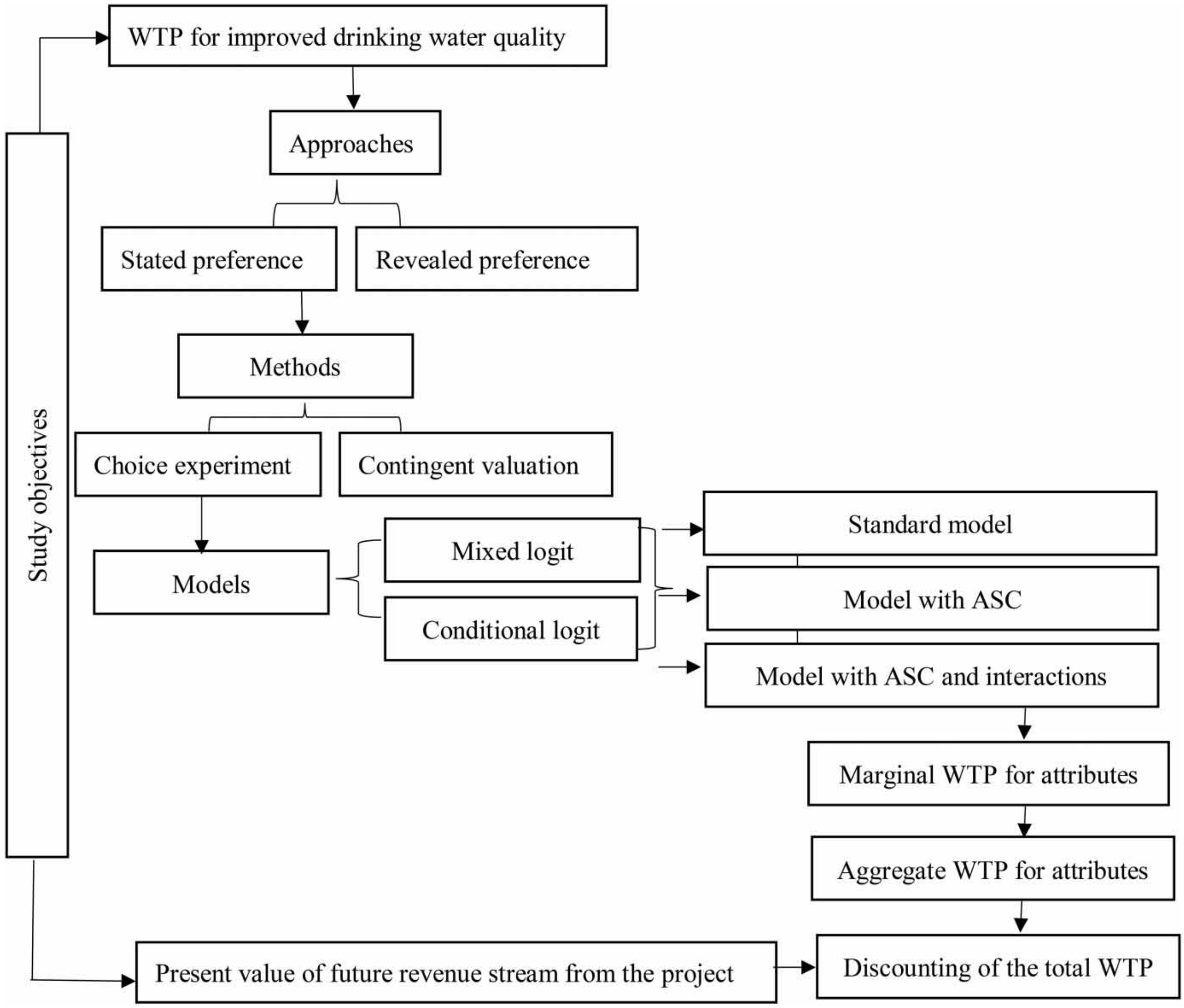

Fig. 1. Flow of methodology. *Source*: Adapted and customized from Ahsan *et al*. (2020).

representative, and two development experts working at NGOs). Their opinions, based on their past working experiences in different drinking water supply projects in Bangladesh, were taken into account when preparing focus group discussion (FGD) checklists. Three FGDs with participants from diverse walks of life in Khulna were conducted in order to identify the most relevant attributes for the study. From these, we selected seven attributes. Two pilot surveys were then carried out to test the selected attributes' relevance at the field level. Based on the response from the piloting, we discarded three attributes that did not have perfect relevance for the study, and thus, the final set was reduced to four attributes only. A choice set with concern attributes and levels as an example is presented in Table 1.

Choice card design with levels and values. Feedback from expert opinions, FGDs, and pilot surveys were successfully used to finalize the attributes when designing the CE. We then reviewed the literature

Table 1. Attributes and levels used in choice cards.

Attributes	Levels	Values	Description
Water Quality	*Uncertain*	*1*	Sometimes water needs to be treated and sometimes not
	Good	2	No treatment is required
Regularity of Water Supply	*Irregular*	*1*	At least two interruptions in a week
	Moderately regular	2	One interruption in a month
	Regular	3	Regular water supply every day
Tap Water Pressure	*Uncertain*	*1*	Inconsistent water pressure
	Low	2	Water never reaches upstairs in a multistorey building
	Medium	3	Water sometimes reaches to upstairs in a multistorey building
	High	*4*	Water always reaches to upstairs in a multistorey building
Filter	*No Filter*	*1*	No filter with tap water
	Filter	2	Filter with tap water
Monthly Cost (in BDT)	*200*	*200*	Per month water cost
	5% increase	210	5% increase in water cost
	10% increase	220	10% increase in water cost
	15% increase	230	15% increase in water cost

The italic figures represent the current levels (*status quo*) of water-related attributes for the households.

intensively in order to assign levels for each water-specific attribute. To minimize the degree of inter-attribute-level correlation, we made the choices orthogonal, which resulted in (2^5=) 32 choice combinations. To reduce the psycho-cognitive pressure on respondents when selecting choice combinations among alternatives, we discarded 14 close choices. From the remaining 18 choice combinations, we prepared a set of six choice cards with three different combinations. Each card contained a *status quo* combination – the same for all cards – and two different combinations for each card. Figure 2 presents an example of a choice card. We approached each respondent and asked them to choose one of these three combinations from the six cards. A choice of *status quo* suggested that respondents had no preference for improvement, while other combinations indicated that respondents did desire improvement.

Based on two specific improvement levels of water supply attributes over the *status quo*, we designed an improved (drinking) water supply with five attributes: (a) perceived quality for drinking, (b) regularity in supply, (c) pressure at the tap, (d) filtering, and (e) price. The surveyors presented different water supply improvement plans using the choice combinations relative to their respective prices in order to become familiarized with the choice tasks. Respondents were shown two samples of choice cards (see Figure 2). However, the surveyors were very likely to encounter the ordering effect's challenge[1] when showing choice cards to respondents. To address this challenge, surveyors were asked to pick cards up randomly (from the set of six cards) so that no two consecutive respondents experienced the exact same ordering of card presentation. In this study, in addition to recording respondents' preference information, data on their socio-demographic features were also collected in order to ascertain the factors affecting WTP for improved drinking water supply in Khulna. In this regard, a payment (cost) attribute, referred to as 'price' and set out as a mandatory monthly payment through mobile phone, was included in the econometric models.

[1] The order of the choice cards when presented to respondents is highly likely to influence their elicitation for preferences (see Day *et al.*, 2012).

Levels	Imaging	Status Quo	Improvement Level 1	Improvement Level 2
Water Quality		Uncertainty in Water Quality	Moderate Water Quality	Good Water Quality
Regularity of water supply		Uncertain	Moderately regular	Regular
Tap Water Pressure		Uncertain	Low	High
Water Filter		No Filter	No Filter	Filter
Expected Monthly Cost (in BDT)		200	210	230

Fig. 2. Example of a choice card.

Questionnaire design. We separated the questionnaire into four sections: (a) respondents' socioeconomic issues, (b) drinking water supply-related issues, (c) the CE issue, and (d) awareness-related issues. The criterion we followed for selecting questions were as follows: (a) reviewing the literature on WTP for drinking water, (b) discussion with experts, and (c) two FGDs with city-dwellers from diverse walks of life. Based on the outcomes from these criteria, we designed our questionnaire with 51 questions within the four sections. In the pilot phase, we pre-tested our questionnaire with 15 respondents in the first round. The questionnaire was then modified based on the first-round piloting and sent out for second-round piloting with 20 respondents. This piloting phase was carried out from December 2017 to January 2018.

Sampling procedure and survey. We followed a multistage sampling procedure at different levels when selecting sample respondents for this study. In this regard, we first randomly selected three thanas[2] – Khan Jahan Ali, Sonadanga, and Khalishpur – from the KCC area as presented in Figure 3. Each thana comprises several wards (Banglapedia, 2014), and therefore, we purposively selected a cluster of wards from the thanas in question based on high, medium, and low population density. From these

[2] An administrative cluster in the city corporation area which consists of a number of wards.

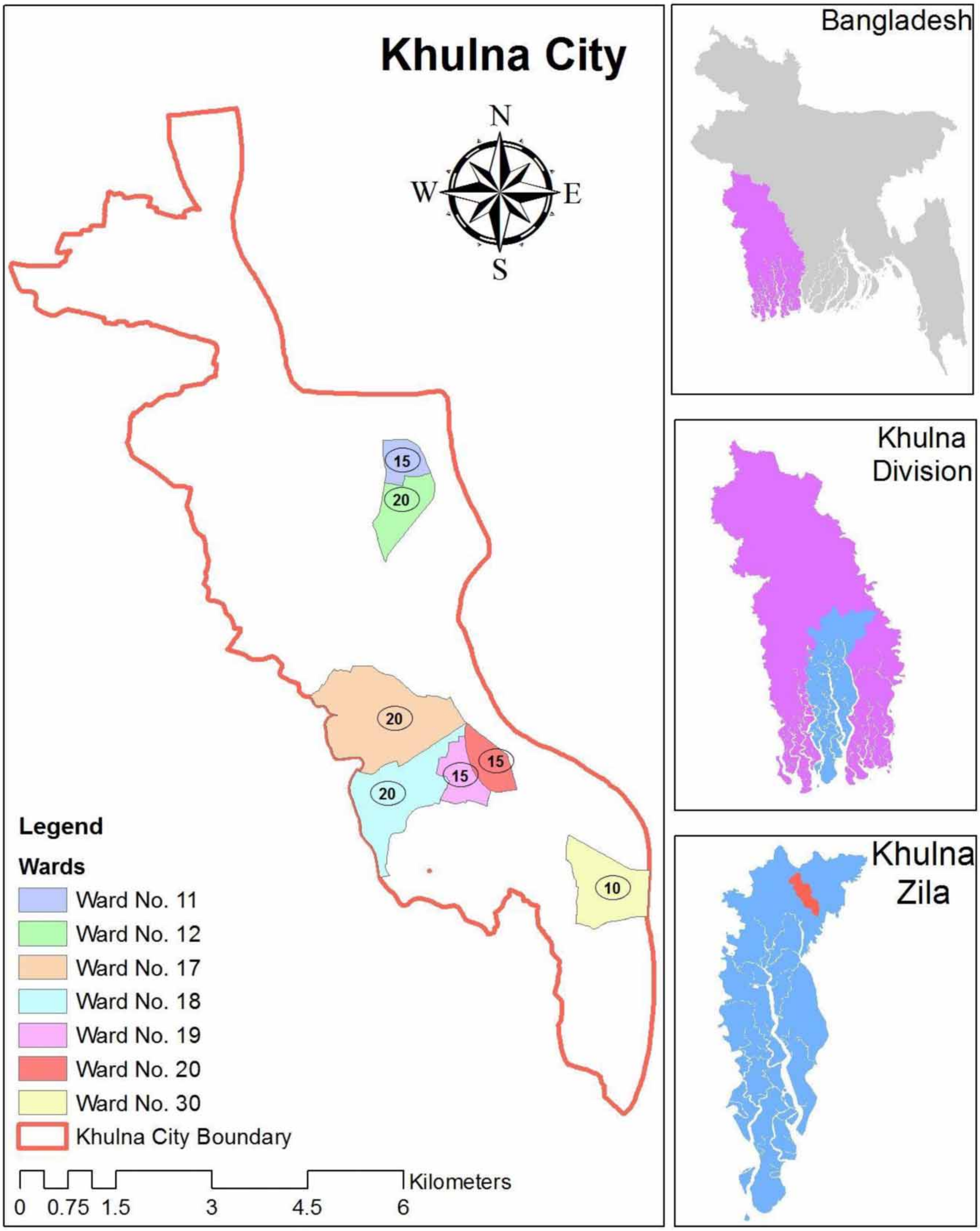

Fig. 3. Locations of the sampled household respondents. *Source*: BBS (2019).

clusters, we randomly selected three wards (numbers 19, 20, and 30) from the Khan Jahan Ali thana, two wards (numbers 11 and 12) from the Khalishpur thana, and two wards (numbers 17 and 18) from the Sonadanga thana (KCC, 2018). We then collected the voter list from the relevant ward councillor's offices. From this list, we randomly selected 57, 53, and 51 respondents from the Khan Jahan Ali, Sonadanga, and Khalishpur thanas, respectively. Thus, in total, we randomly selected 161 respondents for this study. Of these 161 respondents, 46 respondents (nearly 29%) replied negatively in terms of their WTP for an improved drinking water supply. Among these 46 respondents, 31 believed that it was not their responsibility to make a financial contribution to the water supply project, but rather that of the government. Therefore, they were not interested in paying, even though they had the means. These 31 respondents (19% of 161) were considered as protest bidders in this study and were eventually excluded from the sample.

In contrast, 15 respondents (9% of 161) stated that their income constraints made them financially unable to pay for this scheme, though they would be interested in contributing if they could afford to do so. Therefore, these 15 respondents were considered valid responses. We finally conducted a CE and an in-depth face-to-face questionnaire survey with 115 respondents. On completing the experiment, we found that about 87% of the participants in this experiment chose improvement over *status quo* and expressed a positive WTP for the improved attributes of the service. The remaining 13% of respondents chose *status quo* (no improvement) from among the alternatives, although they had been willing to pay for the improvement initially. A plausible explanation is that for these households, the cost of the service might exceed the benefit from the improvement with respect to budget constraints. This social exclusion could give rise to a free-rider problem in society (Islam *et al.*, 2019). However, as the majority of the households stated that they would opt to pay for the service, it is likely that the rest of the households would opt into the service over time as social norms come to play a role (Le Coent *et al.*, 2021). This is because people mimic the actions of their societal peers, which determines whether an activity meets with social approval or disapproval (Aronson *et al.*, 2018). The three thanas of the KCC area from which the households were drawn are shown in Figure 3.

The *status quo* level was assigned to each of the six cards while estimating the WTP for each attribute. Postgraduate and undergraduate level university students were deployed as surveyors; they were trained for 1 week in the field techniques of conducting the CE. This household-level survey was conducted during February–April 2018.

Results

Socioeconomic status of respondents

Table 2 presents several determinants of the socioeconomic status of respondent households. The results suggest that all the respondents were household heads whose mean age was 42.6($\pm$9.4) years. The majority of the respondents in the sample were male (78%). The average household size was estimated at 4.75($\pm$1.47) persons, which is slightly higher than both the regional (4.19 persons) and national (4.06 persons) averages (BBS, 2013, 2016). Literacy status suggests that as urban dwellers, the respondents, on average, had completed 12.8($\pm$3.58) years of academic schooling, implying that they possessed at least a college-level education. The average monthly income of the household respondents was found to be just over BDT 36,000 (≈US$ 424), with a standard deviation of approximately

Table 2. Socioeconomic profile of respondents.

Variable name	Unit of measurement	Mean	Obs. above mean (%)	Standard deviation	Minimum	Maximum
Age of the household head	Number	42.61	**51.3**	9.41	24	66
Household size	Number	4.75	**48.7**	1.47	2	10
Years of schooling	Number	12.8	**48.7**	3.58	3	18
Monthly income	BDT (in '000)	36.01	**61.7**	20.4	10	150
Total amount of assets	BDT (in '000)	1,308	**2.6**	2,227	550	25,000
Monthly water supply interruption	Number	3.24	**60.87**	3.17	2	13
Monthly water cost	BDT	220	**45.48**	137	200	600
Yearly frequency of water-borne diseases	Number	5.72	**33.96**	4.8	0	20
Monthly medical expenditure	BDT	404	**41.74**	328.17	500	2,083

Important/significant values are indicated in bold.

BDT 21,000 (≈US$ 247). Compared with the average monthly income, such a value of standard deviation (58% of monthly income) implies a notable income disparity among the respondents. This scenario is further strengthened by the respondents' asset portfolios, where the relevant standard deviation was found to be nearly 1.7 times higher than the average, as presented in Table 2.

Like the dwellers in the KCC area, people in other areas in Bangladesh depend on groundwater for drinking and other purposes (Karim & Safiuddin, 2003). The empirical findings in Table 2 suggest that respondents, on average, suffered an interruption in groundwater supply just over three times per month, with a similar value of standard deviation. To meet the consumption of drinking water, the average monthly expenditure by households for this purpose was found to be nearly BDT 220($\pm$137) (≈US$ 2.6). The respondents were affected, on average, nearly six times a year by diverse water-borne diseases, and thus had to incur a monthly medical cost of BDT 404($\pm$328.17) (≈US$ 4.76).

Econometric estimations

Table 3 demonstrates the econometric results of six logit models, where the first three models are estimated as conditional logit (CL) followed by three additional ML models. Columns 1–3 in Table 4 exhibit the estimated CL models, and columns 4, 6, and 8 exhibit the estimated ML models' results. Columns 5, 7, and 9 exhibit the relevant standard deviations of the ML models. We estimate WTP variation with the standard model (without an ASC variable) in both the CL and ML models, with an ASC model and an interaction model. Twelve interaction terms are incorporated into the models reported in columns 3 and 8. These interaction terms were obtained by multiplying socioeconomic characteristics with water attributes.

The results of the standard CL model (column 1) in Table 3 suggest that payment vehicle 'price' is negatively associated with the variation of WTP, and it is statistically significant at a 1% level. This finding strongly supports the conventional demand law for an improved drinking water provisioning system, implying that demand for an improved safe drinking water supply reduces with the increase in the price of the improved water supply by KWASA, controlling for other attributes. The coefficients of all attributes were found to be positive. From this point, the signs of coefficients aligned with our expectation, implying that an improvement in drinking water supply attributes positively affects its

Table 3. Econometric results of estimated models for improved supply of drinking water.

	Conditional logit (CL)			Mixed logit (ML)					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Columns	Standard model	Model with ASC	Model with interaction	Standard model		Model with ASC		Model with interaction	
Standard model	Mean	Mean	Mean	Mean	SD	Mean	SD	Mean	SD
ASC		**7.334*****	**7.272*****			29.31	0.0630	39.054	−0.038
		(0.732)	(0.732)			(9,645)	(9,762)	(77,508)	(91,065)
Water quality	**0.861*****	**1.752*****	**0.758****	**1.092*****	**0.884*****	**3.121*****	**1.326*****	**2.668*****	0.461
	(0.234)	(0.272)	(0.364)	(0.274)	(0.203)	(0.506)	(0.354)	(0.688)	(0.482)
Regularity of water flow	**0.424*****	**1.563*****	**1.614*****	**0.593*****	−0.0209	**2.936*****	0.317	**4.006*****	0.157
	(0.142)	(0.174)	(0.205)	(0.146)	(0.161)	(0.345)	(0.212)	(0.574)	(0.284)
Water pressure in tap	0.0197	**0.563*****	**0.725*****	0.0764	**0.329*****	**1.674*****	0.0442	**2.409*****	−0.033
	(0.0699)	(0.0797)	(0.130)	(0.0768)	(0.0685)	(0.187)	(0.205)	(0.347)	(0.169)
Filter	**1.015*****	**2.244*****	**1.660*****	**1.340*****	**− 0.698*****	**4.135*****	**1.162*****	**4.916*****	**− 0.883****
	(0.220)	(0.260)	(0.337)	(0.250)	(0.182)	(0.544)	(0.375)	(0.845)	(0.402)
Price	**− 0.171*****	**− 0.356*****	**− 0.358*****	**− 0.231*****		**− 0.753*****		**− 1.047*****	
	(0.0432)	(0.0480)	(0.048)	(0.0463)		(0.101)		(0.167)	
Quality*income at mean			**0.645***					**1.646****	−0.811
			(0.338)					(0.762)	(0.668)
Regularity*income at mean			0.098					0.057	−0.497
			(0.161)					(0.288)	(0.303)
Pressure*income at mean			0.022					−0.087	**− 0.686****
			(0.141)					(0.263)	(0.270)
Filtering*income at mean			**0.760****					**2.094*****	**2.643*****
			(0.300)					(0.768)	(0.699)
Quality*education at mean			**0.573***					0.671	**− 1.890*****
			(0.335)					(0.649)	(0.612)
Regularity*education at mean			0.005					−0.161	0.300
			(0.157)					(0.272)	(0.216)
Pressure*education at mean			−0.070					−0.059	0.177
			(0.138)					(0.215)	(0.256)
Filtering*education at mean			0.149					0.635	−0.554
			(0.296)					(0.527)	(0.500)
Quality*age at mean			**0.897*****					**2.010*****	**1.048***
			(0.329)					(0.712)	(0.540)
Regularity*age at mean			−0.164					−0.195	**0.614***
			(0.155)					(0.260)	(0.323)
Pressure*age at mean			**− 0.277****					**− 0.498****	0.296
			(0.136)					(0.225)	(0.212)
Filtering*age at mean			0.450					0.020	0.258
			(0.291)					(0.509)	(0.560)
Observations	2,070	2,070	2,070	2,070	2,070	2,070	2,070	2,070	2,070
Log-likelihood	−1,114.18	−771.59	−743.79	−718.39		−337.63		−307.08	
LR	32.31	717.48	773.07	47.36		12.37		29.51	
Prob $> \chi^2$	0.000	0.000	0.000	0.000		0.03		0.03	

Standard errors in parentheses.
$***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

Table 4. Attribute-specific marginal WTP estimation.

	Conditional logit (CL)			Mixed logit (ML)		
Attributes	Standard model	Model with ASC	Model with interaction	Standard model	Model with ASC	Model with interaction
Water quality	5.022	4.916	2.115	4.738	4.1467	2.548
Lower bound estimate	3.371	4.092	0.399	3.247	3.473	1.539
Upper bound estimate	6.672	5.740	3.832	6.229	4.819	3.557
Regularity of water flow	2.476	4.386	4.503	2.571	3.901	3.826
Lower bound estimate	1.768	3.902	3.678	2.071	3.580	3.358
Upper bound estimate	3.184	4.869	5.328	3.069	4.22	4.294
Water pressure in tap	.115	1.579	2.023	.332	2.223	2.301
Lower bound estimate	−.646	1.206	1.333	−.253	1.955	1.926
Upper bound estimate	.877	1.951	2.713	.916	2.492	2.675
Filter	5.921	6.296	4.631	5.811	5.493	4.695
Lower bound estimate	4.278	5.444	3.232	4.505	4.949	3.953
Upper bound estimate	7.565	7.147	6.030	7.117	6.037	5.437

demand. These findings suggest that respondents are willing to pay more for each improved attribute (i.e. water quality, lower/no occurrence of water supply interruption, tap water pressure, and water filter) of the water supply system. All of these coefficients, except tap water pressure, are statistically significant at a 1% level. However, the standard CL model included neither ASC nor interaction terms for respondents' heterogeneous socioeconomic attributes, which would induce specification biases due to the violation of IIA property as mentioned in the 'Experimental design' section.

By following Kouser & Qaim (2013) and Dauda *et al.* (2015) for the standard CL model, we included ASC and interaction terms in the models reported in columns 2 and 3, respectively, of Table 3. Results from the CL model with ASC (in column 2) suggest that the coefficients of improvement attributes on WTP variation are much higher than those in the standard CL model (in column 1) and that all attribute-specific coefficients are positive and statistically significant at 1% level. Similarly, the CL model's payment vehicle 'price' with ASC (in column 2) also exhibits a statistically significant and negative association with WTP variation, having a larger coefficient than the standard CL model (in column 1). In the CL model with ASC term (in column 2), ASC is also found to be positive and statistically significant at 1% level, implying that respondents are, on average, more likely to prefer improved drinking water supply than the *status quo*. Therefore, households have a general tendency to choose an improved water supply system over the current supply system, though none of the CL models (reported in columns 1 and 2) controlled for the effect of socioeconomic features on WTP variation.

Interaction terms for the socioeconomic features are introduced; the attributes of an improved water supply system, CL model with ASC, and socioeconomic interaction terms reported in column 3 of Table 3 exhibit the effect of socioeconomic heterogeneity on WTP variation. This model (column 3) obtained almost similar results for attributes to those yielded from the CL model with ASC (column 2), though 5 out of 12 interacted terms exhibit a statistically significant relationship, with respondents showing a preference for the proposed improvement to KWASA's supply of drinking water. While contrasting these, we found that the relevant coefficients of ASC and price variables reported in columns 2 and 3 of Table 3, respectively, are nearly the same and statistically significant at a 1% level.

Furthermore, the extended model reported in column 3 of Table 3 suggests that households with above-average income are more likely to pay more for improved water quality and regularity in water flow, as the mean coefficients of the interaction of above-average household income with water quality and regularity in water flow attributes were found to be positive and significantly different from zero, respectively. Similarly, we also found that household heads with above-average education and greater age are likely to pay more for water quality, as the coefficients of the respective interactions are obtained as statistically significant. Finally, the coefficient of water pressure interaction with age was found to be negative and statistically significant at a 5% level, implying that older household heads are likely to pay less for high water tap pressure. Hence, this extended CL model, reported in column 3 of Table 3, appears to be more appropriate and robust than the other CL models reported in columns 1 and 2, since this model controls for households' socioeconomic heterogeneity in preference towards improved water supply.

As with the CL models, a class of ML models – standard, with ASC, and an extended model with ASC and interaction terms – were used to estimate households' preference for an improved safe drinking water supply system, as reported in columns 4, 6, and 8 of Table 3. As mentioned in the 'Socioeconomic status of respondents' section, models that do not include ASC or interaction terms would produce biased estimates to some extent; we confined our discussion to the extended ML model that included ASC and interaction terms for socioeconomic characteristics with attributes, reported in column 8 of Table 3.

The results presented in column 8 of Table 3 suggest that all the attributes of an improved drinking water supply system are positive and statistically significant at a 1% level. Similar results were obtained from the three corresponding ML models after controlling for households' heterogeneity in socioeconomic characteristics, implying that households were likely to pay more for additional improvement to each attribute's *status quo*. While contrasting the results of the CL and ML models, we found a difference in their coefficient values, though the relevant signs and significance levels for attribute-specific coefficients remain the same in both the CL and ML models. Furthermore, unlike in the CL extended model, we obtained ASC with a higher value in the ML model, though this was not statistically significant. Therefore, though it cannot be generalized, in the extended ML model results the sampled households exhibited a stronger preference for an improved water supply system than that obtained from the extended CL model in Table 3.

Similarly, the price effect on preference for the improved water supply system in the extended ML model exhibited a value nearly three times higher than the extended CL model's respective effect. This implies that households' demand for an improved water provisioning system is very sensitive to price changes. Furthermore, each attribute's improvement has a greater effect on WTP in the extended ML model than in the extended CL model.

WTP estimation

Table 4 presents the marginal WTP in percentage for a respondent household for proposed improvements to the safe drinking water supply by KWASA. Both the CL and ML model estimates with upper and lower bound are presented in Table 4.

As expected, the respondent households exhibit positive marginal WTP in terms of increasing percentage for the improved attributes of safe water supply by KWASA, as presented in Table 4. For both the CL and ML models, the highest percentage increase was found for filter attribute (this was greater with each level of improvement from the *status quo*), followed by the water quality, regularity of water flow, and water pressure in tap attributes, respectively.

In this study, the improved water supply system's payment vehicle is the *change* in water price (measured in percentage) from the *status quo* level water price. Therefore, there is a trade-off for households between water price and improvement of water attributes, implying that households are required to pay more (in percentage) for switching to a higher level of improvement to a varying mix of water attributes. Thus, respondent households' MWTP was computed from the marginal rate of substitution (MRS) between the attribute coefficient and the coefficient for the payment vehicle 'price'. Attribute-specific marginal WTP and WTP (at mean level) are reported in Table 5.

Following Rai *et al.* (2018), we computed the attribute-specific WTP as reported in column 3 of Table 5. The results from Table 5 suggest that the average household is willing to pay an additional 2.5% of the current water price for water quality improvement from the *status quo* (from uncertain to sound quality), implying that the household has an additional WTP of BDT 5.1 (≈US$ 0.06) per month for improved water quality. Furthermore, the household is willing to pay an additional 3.8% of the current water price for an improvement in regular water flow from the *status quo*, implying that the household has an additional WTP of BDT 15.3 (≈US$ 0.18) per month for increasing the regularity of the water supply from irregular to regular. Similarly, the household is willing to pay an additional 2.3% of the current water price for an improvement in tap water pressure from the *status quo*, implying that the household has an additional WTP of BDT 13.8 (≈US$ 0.16) per month for water pressure improvement from uncertain (i.e. inconsistent) to high. Finally, the household is willing to pay an additional 4.7% of the current water price for an improvement in filtering water at the source from the *status quo*, implying that the household has an additional WTP of BDT 9.39 (≈US$ 0.11) per month for the ability to avail filtered water. Therefore, the results from Table 5 suggest that the average household has an additional WTP of BDT 43.6 (≈US$ 0.51) per month over the current cost (BDT 200/month) in order to avail improvements to the attributes of a safe drinking water supply from KWASA. Thus, the household's total WTP would be BDT 243.6 (≈US$ 2.87) a month for availing the supply of safe drinking water.

Welfare gain determination

Based on the results from Table 5, households exhibited the highest WTP (BDT 15.4/month) for regularity of water flow, which became greater with each level of improvement from the *status quo*. The next highest WTP was demonstrated for tap water pressure, implying that the sampled households

Table 5. Marginal WTP estimation.

Attributes	Marginal WTP (in BDT)	Difference in attribute level (Δk)	Attribute-specific total WTP[a] (in BDT)
Column	1	2	3 (=1*2)
Water quality	2.5% of 200 = 5.1	1	**5.1**
Regularity of water flow	3.8% of 200 = 7.7	2	**15.4**
Water pressure in tap	2.3% of 200 = 4.6	3	**13.8**
Filter	4.7% of 200 = 9.39	1	**9.39**
Household-level total additional WTP			**43.6**

[a]WTP is computed by following Hanemann (1984).

were willing to pay BDT 13.8 per month for each level of improvement from the *status quo*. Next was switching to filtered safe drinking water, with a WTP of BDT 9.39/month to improve on the *status quo*. The lowest WTP (BDT 5.1/month) was demonstrated for water quality. The overall result from Table 5 suggests that households were willing to pay BDT 5.1 per month for each increment towards a higher level of water quality, starting from the *status quo*.

The households' computed additional WTP for an improved safe drinking water supply system is BDT 43.6 (US$[3] 0.51) per month, as exhibited in Table 5; this constitutes 22.8% of the current water price. From this estimate, we can compute a community water fund (CWF) for an improved safe drinking water supply system, to be generated annually by households in the KCC area, using the formula:

$$\mathrm{CWF}^4 = (\mathrm{WTP}_h)\left(1 + \frac{r}{100}\right)^t \times \mathrm{HH}(1.01)^t \times \mathrm{Probability} \times 12 \text{ months}$$

where r is the annual increment rate and t is years. KWASA needs to provide a water connection to more than 0.3 million households in the KCC area (KCC, 2020), and the number of households is expected to grow at a 1% rate over the next 25 years (Worldometer, 2020). The results show that the probability of households who participated in the CE being willing to pay for an improved safe drinking water supply system is 87%. Based on this information, the estimated CWF for the year 2020 is around BDT 812 million (≈US$ 10 million); households would be able to transfer money to KWASA to improve the water provisioning system. This estimated WTP can be considered the minimal amount of revenue for prospective investment by KWASA. Table 6 presents a 25-year cumulative revenue generation projection based on population and annual 5 and 10% interest adjustment to WTP, implying a lucrative investment prospect for KWASA to provide improved safe drinking water to city-dwellers. Furthermore, this future investment scenario shows that KWASA is likely to generate US$ 42 and 133 million in the year 2045 following a 5 and 10% annual interest rate adjustment in the water tariff. The present value of cumulative revenue generation from this KWASA project is US$ 168 and 115 million at a 5 and 10% discount rate. This can be considered a 'no-regret' approach, as the computed amount for CWF is conservative by estimation.

Discussion

This study has estimated households' monthly WTP and examined the initial revenue-generation prospect for the improved drinking water supply project proposed to take place over 25 years in the KCC area. About 87% of households that participated in the CE expressed a positive WTP for an improved safe drinking water supply. The remaining 13% of respondents chose the *status quo* (no improvement) out of all the alternatives, although they had been willing to pay for the improvement initially. These households might deem the cost of the service to be greater than the benefit derived from the improvement with regards to budget constraints. The significant contribution of this study is that it precisely

[3] 1 US$ = BDT 84.95.

[4] $\mathrm{WTP_h}$ refers to WTP per household; probability is the percentage of households interested in availing the KWASA connection; HH is the total households in the KCC area.

Table 6. Prospective additional revenue stream for improved safe drinking water supply.

Year	WTP (BDT/month)[a]		Future value of annual CWF (million BDT)[b,c,d]		Future value of annual CWF (million USD)		Present value of cumulative CWF (million USD)	
	Interest rate						Discount rate	
	5%	10%	5%	10%	5%	10%	5%	10%
2020	244	244	812	812	10	10	10	10
2025	311	392	1,089	1,374	13	16	52	47
2030	397	632	1,461	2,327	17	27	88	72
2035	506	1,018	1,960	3,938	23	46	119	90
2040	646	1,639	2,629	6,666	31	78	145	104
2045	825	2,639	3,526	11,283	42	133	168	115
Total			**48,393**	**105,615**	**570**	**1,243**	**582**	**438**

[a]This study considers two increment/interest rates, 5 and 10% on water tariff, for computing the future value. Future WTP = (Base WTP) × (1 + interest rate/100)^time.
[b]The total population of Khulna is 1.5 million (KCC, 2020), the household size is 4.75 (Table 2), and the population growth rate is 1.01 (Worldometer, 2020). Therefore, the number of households = (total population/household size) × (population growth rate)^years.
[c]As of this study, 87% of total households are considered for the years in question, as this percentage of households agreed to avail of the improved water supply. Therefore, the number of agreed households = the number of households × 0.87.
[d]This figure is obtained using the formula: BDT Future WTP × 12 × the number of agreed households.

estimates households' average WTP as BDT 243.6 (≈US$ 2.87) per month, generating a CWF of BDT 812 million (≈US$ 10 million) for an improved water quality service in the year 2020. Over the initial 25-year lifespan of this project, the revenue stream would generate cumulative revenue worth US$ 570 million and 1.243 billion at 5 and 10% interest, respectively. The present value of this project's total revenue generation is US$ 582 and 438 million at a 5 and 10% discount rate, respectively (see details in Table 6).

This study has four main findings. First, the sampled respondents exhibited a general tendency to choose the improved water supply system over the existing system, implying that there is demand for this improvement plan. Second, all the improved water supply system attributes – water quality, regularity of water flow, water pressure, and filtering option – were positively associated with WTP, showing that households were willing to pay more to improve these attributes. Third, household heads with above-average income were likely to pay more for water quality and filtering options, while those with above-average education were likely to pay more for water quality only, and household heads of above-average age were likely to pay more for water quality and water pressure. Therefore, all household heads with higher income, above-average education, and greater age were ubiquitously likely to pay more for water quality improvement. Fourth and finally, respondents placed most emphasis on regularity in water flow; they were willing to pay more to ensure uninterrupted water flow with ascertained water quality.

Though the respondent households exhibited a WTP for improved attributes (i.e. quality, regularity, pressure, and filter) of the water supply, the amount that the respondents were inclined to pay for each attribute and their prioritization of the attributes were not the same. Table 5 shows that, among the four attributes, households demonstrated the highest WTP (BDT 15.4/month) for regularity of water flow. In contrast, the lowest WTP (BDT 5.1/month) was exhibited for improvement in water quality.

Furthermore, Table 2 shows that the average and maximum numbers of monthly water supply interruptions were 3 and 13 days, respectively; these were suffered by nearly 61% of the respondents. In contrast, the average and maximum numbers of water-borne disease incidences were 6 and 20, respectively; these were suffered by nearly 34% of the respondents. This suggests that respondent households suffered from both the quantity and quality of the existing water supply. The results suggest that households' WTP was higher for water supply regularity than for water quality improvement. This is an interesting and unusual attitude from the households, as many previous studies have shown that households are inclined to pay relatively more for water quality than other attributes (Wang *et al.*, 2018). A justification for such an unusual finding might be that in urban areas of Bangladesh, it is a common practice for most non-poor households to boil and/or filter water inside their homes in order to have a better quality of drinking water (BBS and UNICEF, 2018), but they struggle to access a consistent supply of drinking water, especially during hot summers (Mensah, 2018).

Furthermore, unlike the initiatives for water quality improvement mentioned earlier, households depend solely on the water supply agency to access a regular water supply, as this agency is the only water supplier. Nonetheless, in a tropical country, it is hard to spend even a single day without a supply of drinking water. Therefore, even though the water supply was only interrupted on an average of three (3) days and a maximum of 13 days per month, it appeared to the household respondents that this was the most severe problem, which meant that they were inclined to pay more to ensure the regularity of the drinking water supply.

Scientists consider water quality an important issue, as compromising on it may invoke health risks for humans (de França Doria, 2010). Though health risk perception is not symmetric among all people, research shows that demographic features are often weakly but significantly associated with risk perception (de França Doria, 2010). For example, risk perception is not the same among men and women; generally, women perceive higher risks and express more concern than men, according to a study by Chew *et al.* (2019). In the current study, 78% of the respondents were male, and so their relatively low-risk perception might lead them to view water quality as a low priority. This study's findings suggest that the respondent household heads' age, education, and income had a positive and significant association with WTP in terms of improved water supply attributes. These findings are consistent with the findings of Nielsen *et al.* (2003). Finally, it can be concluded that households' risk perception and socio-demographic characteristics play a significant role in determining the degree of priority among the attributes for which households expressed their WTP in terms of the supply of improved safe drinking water in the KCC area.

Concluding remarks

Due to climate change, scarcity of safe drinking water is not an uncommon scenario globally, especially in the urban areas of developing countries. To mitigate this scarcity, necessary adaptation measures need to be carried out by ensuring a consistent supply of safe drinking water that satisfies both the demand and supply sides. This study has mainly focused on the demand side by estimating households' WTP for an improved drinking water supply by KWASA in the KCC area of Bangladesh through the application of a CE method. In this regard, the study has also estimated households' preference in terms of WTP for attribute-specific improvement of the drinking water supply by KWASA. The study has made two significant contributions. First, it has included and tested how households' socioeconomic characteristics might affect their demand for safe drinking water via respective preferences. Second, it has provided an investment prospect for water supply agencies, which could help policymakers to make future decisions.

The study's significant empirical results suggest that the sampled households in the KCC area exhibited a WTP for the proposed improvement to the existing drinking water supply system. In this regard, they were ready to pay a total of BDT 243.60 (≈US$ 2.87) per month, which is nearly 0.67% of their monthly income. In other words, households were willing to pay an additional BDT 43.6 a month over their existing monthly water bill of BDT 200. Of this computed additional amount, they were most willing to pay for regularity of water flow (35.2%) followed by tap water pressure (31.7%), filtering (21.5%), and water quality (11.7%), respectively. Furthermore, a multi-decade investment prospect of a CWF for KWASA to improve the attributes of safe drinking water has shown a cumulative revenue generation worth around US$ 570–1,243 million over 25 years. The substantial present value of revenue from this project would vary from around US$ 438–582 million, which appears to be financially viable over the long run and henceforth can be considered a 'no-regret' strategy for improving the existing drinking water supply system. In line with the empirical findings of this study, we propose the following three policy recommendations:

First, KWASA could establish several water reservoirs to ensure the regularity of water supply in the KCC area, especially during hot summers when the demand for water increases and water availability is affected due to shrinking groundwater levels. Water availability in the *Modhumati* river, which is currently the primary water source of KWASA's ongoing water supply project, can fluctuate for any climatic reason. These proposed reservoirs could be used to mitigate the challenges mentioned above by storing water used by city-dwellers, purifying it, and reusing it over a specific duration all year round. In this way – by incorporating reservoirs – the whole water supply system can be made efficient and sustainable. For the water reservoirs, incorporation of canals, wetlands, and the water retention ponds of KCC would be a possible option. In this regard, KWASA should make an integrated plan with KCC in order to benefit from the latter's wetland management plan and land use plan.

Second, the capacity of KWASA needs to be enhanced in order to ensure a better water supply service in the KCC area. In this regard, KWASA could establish an operation and monitoring system by introducing automation and good governance. This would enhance efficiency in all its operational segments, namely water collection, treatment, supply, and reuse in the KCC area. Furthermore, by practising good governance, institutional accountability for these functions can be ensured, and in this way, KWASA would become a trustworthy service provider. In addition to this, a wing of Research and Development (R&D) could enhance the quality operation of KWASA. This R&D wing could conduct periodical research related to water supply demand, WTP, and priorities relating to demographic, socioeconomic, and locational features. This R&D wing would continue with research and development initiatives in order to understand residents' choices, demand, and priorities, thus ensuring better use of their revenue and sustaining KWASA's operation and development plan.

Third, this project requires financial viability support as it has a very lucrative investment prospect via the CWF. In this context, a smooth financial operation would ensure such viability. This operation could be made possible by introducing 'financial inclusion' services, i.e. transactions through mobile phones or computers. As these services are already available and popular in Bangladesh (e.g. bKash, Rocket, Sure Cash, etc.), KWASA could avail of this opportunity by integrating such services with its financial system. This would make the monthly payment very easy for consumers and provide an easy application process for water supply connection at the household level in the KCC area.

There is a scarcity of studies attempted to compute WTP for safe drinking water in the urban areas of Bangladesh. Sehreen *et al.*'s (2019) study which is one of these few studies estimated the mean WTP for the capital Dhaka city BDT 511 (about US$ 6). That WTP for Dhaka city is more than double of WTP

(US$ 2.87) for Khulna city. However, WTP as a percentage of income for Dhaka city is around 0.96%[5], which is somewhat close to that for Khulna city 0.68%. Households' higher income level might be the plausible reason for higher WTP in Dhaka city. Although this study estimates WTP for an urban area (Khulna city), it is also comparable with WTP estimates for south-western peri-urban areas. For example, Islam *et al.* (2018) estimated a mean WTP of US$ 3.11 per month for safe drinking water in the Dacope sub-district, while Islam *et al.* (2019) estimated an average WTP of US$ 2.47 for the Mongla sub-district. In these studies, household head features, i.e. income, education, and age, were found statistically significant factors as similar to this study in determining WTP variation for safe drinking water in Bangladesh. The comparison of our estimates with the estimates for some other South-Asian cities reveals that the residents of Khulna city are willing to pay much more than the monthly WTP (US$ 0.70) of the residents of Lahore city in Pakistan but much less than residents' WTP (US $ 7) of Thimpu city in Bhutan (Akhtar *et al.*, 2018; Dendup & Tshering, 2018). Residents of Chennai city of India are willing to pay approximately US$ 5 per month, which is also larger than what residents' WTP of Khulna city.

This study has not included any of the slums in the study location, and therefore, no analysis for WTP determination of households with very low income was performed. Henceforth, future similar studies may address this by including samples from both slum and non-slum areas, and contrast the WTPs from the two types of area. The choice preference approach used in the study, CE, cannot account for features such as water scarcity-induced mitigation expenditure, averting behaviour, and workday loss of the exposed respondents (Alberini & Krupnick, 2000). Furthermore, this study's findings are based on a relatively small sample, and so we should be careful about generalizing them. For security reasons, the prior permissions and appointments impeded our effort to conduct interviews on a larger scale. However, non-market environmental valuation studies are not uncommon in the literature (Islam *et al.*, 2020). We call for further studies that include more water attributes and water pollution-related exposure-specific features; this would provide a large dataset to validate our study findings.

Data availability statement

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

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[5] Authors calculate WTP as a percentage of income for Dhaka city by employing information given in Sehreen *et al.*'s (2019) study.

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