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Preferences for improved early warning services among coastal communities at risk in cyclone prone south-west region of Bangladesh

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ABSTRACT

Cyclone early warning systems are the primary sources of information that enable people to develop a preparedness strategy to mitigate the hazards of cyclones to lives and livelihoods. In Bangladesh, cyclone early warnings have significantly decreased the number of cyclone related fatalities over the last two decades. Nevertheless, several challenges remain for existing early warning services (EWS), urging for both technical and non-technical improvements in the said services. Given limited financial resources, the economic efficiency assessment of the improvement is highly important. Therefore, this study aims to estimate the willingness to pay (WTP) for improved warning services by considering the at-risk households' trade-off between proposed improved EWS and existing EWS in coastal Bangladesh. Applying systematic random sampling, 490 respondent households were selected from Khulna, Satkhira, and Barguna districts, with whom a choice experiment (CE) was performed. The CE was designed by incorporating impact-based scenarios for improved EWS. As analytical tools, Conditional and Mixed-Logistic regression models were used that derived the WTP for improved EWS attributes. Empirical results show that the WTP of an at-risk household for improved EWS was estimated at Bangladeshi Taka BDT 468 ($\approx$ US$ 5.57) per year, implying respondents were ready to pay for the improvement of the warning attributes, including precise information of the cyclones landfall time with possible impacts, more frequent radio forecasts, and voice messages in the local dialects over mobile phones. A revenue stream for improved EWS was developed, implying investments in EWS would be a no-regrets approach. This study concludes with four policy recommendations on mitigating the existing challenges for improving EWS in Bangladesh.

1. Introduction

The Fifth Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC) suggests that globally the frequency of tropical cyclones is likely to either decrease or remain unchanged in the future. In both cases, the intensity of such extreme events is expected to increase, with heavier precipitation and higher maximum wind speeds [1]. The rapid dissemination and notification of cyclone-warnings is extremely difficult for developing nations like Bangladesh, which often results large volumes of damage along with casualties. Nearly 10% of the world's tropical cyclones form in the Indian Ocean and its immediate vicinity in the Bay of Bengal [77]. The emergency event database (EM-DAT) of the Centre for Research on Epidemiology and Disasters (CRED) suggest since 1990s Bangladesh incurred 145,871 human deaths, 40.5 million affected people, 1.7 million homeless people, and an economic loss of US$ 5.12 billion due to tropical cyclones [78]. The said economic loss is equivalent to nearly 3.74% of total economic loss incurred in the South-east Asia due to tropical cyclone over the same time period [78]. The World Meteorological Organization [WMO], along with other concerned agencies, states that the primary cause of these high damages and casualties lies in the difference between the understanding by at-risk people of the perceived forecasts (along with advisories) and their perception of the imminent risks. [2,72].

During rapid onset hazards (i.e., tropical cyclones) the protective actions chosen by at-risk communities largely depends on their risk perception [3]. Empirical findings from previous studies suggest that people at risk are more likely to trust and respond to a warning message if they understand the warning message, possess proper knowledge about the hazard event and understand the potential impact(s) [4,5]. This implies the necessity of capacity for generating coastal inundation forecasts with sufficient lead-time and an acceptable degree of accuracy based on an end-to-end early warning framework, which would make the people appropriate, timely, and life-saving decisions during imminent cyclone emergencies [73]. In developing countries, stakeholder agencies and the people at risk

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find it difficult to visualize the true impacts from a tropical cyclone and its associated surges. For developed countries, a weak positive correlation occurs between an individual's knowledge of hazards and their chosen protective actions [6] while this correlation is high between the experience on the potential impacts and protective actions [5], which is also true for developing countries [7]. Compared to developed countries, coastal populations at risk in tropical cyclone-prone developing countries possess either inadequate or no literacy. As a result, in these countries tools such as flags, pictures, megaphones, and drumming are commonly used as early warnings [8], although in most cases, people at risk still fail to perceive the essential meaning of an early warning message and forecast. For instance, people with very little or no literacy cannot perceive the destructive capacity of an 80–100 km/h wind gust, but they can understand the ability of strong winds to uproot their bamboo-constructed houses. Research shows that before deciding to take a disruptive and often expensive action such as evacuation, people must understand the forecast, believe it applies to them and, most importantly, feel that they and/or their loved ones are at risk [17,24,25].

Since people in hazard-prone areas are the ultimate end-users of warnings and advisories, it is essential to improve the tropical cyclone early warning services (EWS) based on these people's specific needs. Estimation of monetary values and return on investment can be used to evaluate whether such improvements would provide a higher payoff to society than any other homogenous alternative public investments [9]. Improvements in tropical cyclone EWS can be considered as a *no or low-regret* approach for adaptation to climate change impacts that would eventually provide benefits under diverse and uncertain future climate change scenarios [10]. Both the Sendai Framework for Disaster Risk Reduction (SFDRR) and Sustainable Development Goals (SDG) have emphasized EWS as a means of reducing damage and loss from natural hazard triggered disasters [74]. From a Disaster Risk Reduction (DRR) perspective, an improved multi-hazard impact based EWS can play a role in effective preparedness, which is likely to save not only lives, but also critical assets and livelihoods. Investing in preparedness saves thousands of lives and billions of dollars later is well proven [11]. A recent study also suggests that every US$1 invested in EWS generates a return of US$ 6 [12]. Given this background, there is an urge to integrate the adaptation option of improving cyclone EWS with DRR practices by performing efficiency assessments developed within an economic framework.

Climate sensitive developing countries encounter financial constraints and generally, available funds are allocated on basis of need [13]. To ensure the best use of financial resources, an improved EWS as an adaptation strategy would require an economic analysis of benefits. Analysis of the results would aid governments in making informed and appropriate investment decisions. The benefits of improved cyclone EWS are diverse:

- At-risk households are able to fully comprehend the most likely destructive scenario from the cyclone threat and take effective measures to reduce the damage of their properties
- They can reduce their morbidity and mortality likelihoods.
- They can avoid shadow/unnecessary evacuations or a false sense of security
- They can increase their altruistic values
- Local businesses can avoid or minimize supply-chain losses
- The government can avoid significant, unnecessary expenditure on socioeconomic infrastructure [9].

To date, a significant number of studies have comprehensively addressed cyclone evacuation issues in climate sensitive and disaster prone South Asian countries, especially in Bangladesh [7,8,20,24,25,30,82]. However, very little attention is paid to quantitative assessment of at-risk coastal households' preferences for improved cyclone forecasts and EWS as the available handful of studies addressing EWS in Bangladesh mainly focused on indigenous early warning indicators [81], storm forecasting process [30], and features of EWS responsible for non-response toward evacuation [80]. Considering the global perspective- Lazo and Chestnut [14] and Lazo et al. [34] were the pioneers in performing the quantification of benefits from improved EWS in a developed country (United States), while Nguyen et al. [15] performed the very first study on quantification in a developing country (Vietnam). However, neither took impact-based forecasts and warnings into account.

In Bangladesh, over last several decades though EWS incorporated a number of improvements resulting significant decrease in casualty, still it encounters challenges [18]. These challenges particularly indicate accuracy and reliability of cyclone early warnings. For instance, during super cyclone Sidr in 2007 (14 and 15 November), Storm Warning Centre (SWC) of the Bangladesh Meteorological Department (BMD) issued seven special weather update bulletins (sl. no. 13–19). In bulletins 13–17, BMD forecast the danger level for both river and maritime ports (in Chottogram[1] and Mongla) was 4 (wind speed in between 51–61 km/h); while in bulletin 18, the danger level had suddenly changed from 4 to 10 (wind speed ≥171 km/h) for Mongla maritime port and from 4 to 9 (wind speed ≥ 118 km/h) for Chottogram maritime port [30,82]. Such a significant variation in two consecutive warnings put people at risk due to confusion and this led to mistrust of the warning system and advisories. During the recent cyclone Fani (May 2019), BMD declared danger level 7 for Mongla maritime port, including greater Khulna and Barishal region [67]. Forecasts suggested that the tentative trajectory of cyclone Fani would be over the southwestern coastal region. Accordingly, people at risk were forced to move to cyclone shelters in advance and the highest level of preparedness was ensured. However, this cyclone changed its trajectory and did not make complete landfall in the southwestern coastal region of Bangladesh, resulting in no major damage [68,79]. This created a notion of a false alarm among at-risk coastal populations, as reported by a recent study by Rahman [69]. These examples illustrate the limitations of BMD in preparing accurate forecasts, along with precise timing of a cyclone's landfall.

Search results from Scopus and Web of Science imply a knowledge gap in the quantitative estimation of improved EWS in Bangladesh, as no study has been conducted on this issue to date. Therefore, in this study, we attempt to derive the willingness to pay (WTP) for improved warning services by considering the at-risk households' trade-off between proposed improved EWS and retaining existing warning services. In addition, this study develops an investment prospect for improved early warning system incorporating a revenue stream. This ground-breaking study is the first undertaken in Bangladesh that provides estimates of the economic benefits (in terms of WTP) of improved EWS, taking impact-based forecasting options to household level via a Choice Experiment (CE) method.

We introduce the warning dissemination mechanism in Bangladesh in Section 2, and the study materials and methods, including CE procedure details, in Section 3. The results are explored in Section 4, while Section 5 contains a discussion on the WTP and welfare gain. Our concluding remarks and recommendations can be found in Section 6.

2. A glimpse of the cyclone early warning dissemination process in Bangladesh

Due to its geographical location, Bangladesh is highly prone to cyclones. Furthermore, it has a funnel-pattern coastline that seizes cyclone storm surges. This geographical feature propagates increased surge heights at the northern part of the Bay of Bengal [16]. Bangladesh has 19 coastal districts. Almost 49% of the population lives in low-lying areas [17]. On average, 17 tropical cyclones form in the Bay of Bengal annually, either in early summer (April–May) or in the late rainy season (October–November) [18–20]. One severe cyclone strikes coastal Bangladesh every three years [21]. The emergency event database (EM-DAT) of the Centre for Research on Epidemiology and Disasters (CRED) suggests that 163,000 people have been killed by tropical cyclones in Bangladesh over the last three decades (1988–2018). This represents 49.06% of the total fatalities from all other natural hazards during the same period. Furthermore, Bangladesh has

[1] Previously known as Chittagong.

incurred estimated economic damage losses of US$ 2.43 billion due to tropical cyclones, which is 46.74% of the total damages caused by all other natural hazards during the same period [22].

The SWC of BMD prepares all weather forecasts and cyclone hazard warnings. Based on the information obtained from radar observations, satellite imagery, field observatories, and the Regional Specialized Meteorological Centre (RSMC) of New Delhi, the SWC disseminates cyclone forecasts and advisories to different media (television, radio, and newspaper) and the headquarters of the Cyclone Preparedness Programme (CPP). The CPP then forwards the information to different coastal zonal offices (district level administration), the zonal offices pass the information to Upazila (i.e. sub-district) Disaster Management Committees (UzDMC), while the UzDMC pass it on to the Union Level Disaster Management Committees (UDMC). Finally, the UDMCs make the necessary arrangements to disseminate the information among the Ward Level Disaster Management Committees (WDMC), which convey warning-messages and advisories to the people at risk [18,23–25]. Currently, an Interactive Voice Response (IVR) based early warning service, which is accessible over any of the existing mobile phone operators, is available in Bangladesh. With a specific dialing number '10941', this service provides information about five issues/hazards - daily weather forecast, rainfall, cyclone, flood, and landslides, at a cost of BDT 2.15 (US$ 0.026) per minute [26]. The warning delivered from the SWC (three times a day) is free of charge and is the primary source of information for at-risk coastal people. By and large, coastal dwellers access this via television or radio. In addition, they receive warnings from megaphones, peer groups, door-to-door alerts from the local police, warning-flags, hand-sirens, GO/NGO workers, and mosque-mikes in the event of any imminent hazard [8]. For on-shore people, the SWC disseminates forecasts with a lead-time of 24–96 h, while for those off-shore (mostly fisherman at sea) this lead-time is just 12 h [27]. Several recent reports reveal a large number of fishermen, along with their fishing-boats, went missing in the Bay of Bengal during cyclonic storms in July 2018 [28,29], likely due to the inefficient dissemination of early warnings. Furthermore, the poor accuracy of cyclone landfall trajectories has posed a challenge in recent years [30]. Such issues imply that the existing EWS of the BMD, when compared to National Hurricane Center (NHC) in USA and Japan Meteorological Agency (JMA), appears to be inefficient in preparing credible warnings and reliable forecasts for complex, rapidly-formed, and fluctuating tropical cyclones.

3. Materials and methods

In literature, there are two widely accepted and applied approaches, namely- (i) stated preference and (ii) revealed preference to derive the value of environmental goods and/or services. Stated preference approach deals with non-market valuation of a good/service under hypothetical scenarios while revealed preference deals with the good/service for which market exist [15,31–34,84]. As, in this study, we attempt to value a non-market early warning service (EWS) with hypothetically improved attributes [15,34], we adopted stated preference approach, which further consists of two popular and common methods: (a) contingent valuation method (CVM) and (b) choice experiment (CE). Of these two methods, CE is more holistic approach than CVM as the former provides a set of alternatives with different level of attributes and an individual's true preference comes out from his/her choice decisions [15,31–34,40].

In order to perform CE, designing of efficient choice cards is required with appropriate selection of the attributes. Having collected the data using finalized choice cards, in this study we performed econometric techniques to obtain results of CE by using- (i) Conditional Logit (CL) and (ii) Mixed Logit Model (ML). Both CL and ML are employed with three distinct functional forms: (a) standard, (b) with ASC, and (c) ASC with interaction terms (six models were run). We, then computed marginal willingness to pay (MWTP) for each attribute from these six models. As CL class model is characterized with certain limitations, ML class model is often preferred for obtaining reliable results in literature [44,45,64,65]. For this reason, attribute specific MWTP from ML with ASC and interaction model is more precise and efficient. By instrumenting these MWTPs, we realized our first objective – (average) willingness to pay (WTP) for the proposed attribute specific improvement. Finally, (average) WTP was used to realize our second objective: the present value of future revenue stream from improved EWS over its project life (see Fig. 1). The details of the aforementioned processes are discussed in subsequent subsections.

3.1. Choice experiments as a means to evaluate preferences for improved EWS

Choice Experiment (CE) method is frequently applied for economic benefit estimations in situations where no market exists for goods/services that can be valued. Applying the CE method, it is possible to determine a respondent's preferences for a set of relevant product/service attributes and their improvement levels. Together with the average value of willingness to pay (WTP), the CE method also provides marginal values for improving warning services. These marginal values can be useful in order to obtain values for specific improvement options of EWS for households at risk. While developing the improvement attributes in this study, we considered both technical (e.g. meteorological) and non-technical (e.g. communication, perception, and response) aspects of EWS. We adapted and customized two warning service improvement attributes (forecast accuracy and update frequency) from the study of Nguyen et al. [15]. In addition, we introduced two improvement attributes (radio forecast frequency and voice messages in local dialect over mobile phones) in this research. These improvement attributes (update frequency, radio forecast, and voice messages in local dialect via mobile phones) were designed on the basis of impact-based scenarios.

CE is a combined application of Lancaster's [35] model of consumer choice and random utility theory [36–39]. As this study intends to assess coastal at-risk households' preference for improved early warnings, CE would be a useful tool for assessing multi-attribute services like cyclone warning systems [15,40]. In line with random utility theory [37], the CE method assumes that respondent *i* has *j* improved early warning alternatives available from a choice set *C*, providing different levels of utility; and from those available alternatives respondent can choose their preferred option. The utility (U_{ij}) function for a respondent consists of a deterministic component (V_{ij}) and a stochastic component (ε_{ij}) *in the following way:*

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

From the alternatives, respondent *i* chooses a specific improvement program *k* (out of *j*) if and only if $U_{ik} > U_{im}$. Here, the underlying assumption is- ε_{ij} *is Independently and Identically Distributed (IID) with type-I extreme value distribution and fixed variance. Now, the probability (P_{ik}) of choosing k can be expressed as a logit function as follows-*

$$P_{ik} = \frac{\exp(V_{ik})}{\sum_{j=1}^{J} \ expV_{ij}} : \mathrm{k}\epsilon J \tag{2}$$

This can be estimated with the following Conditional Logit (CL) model [15,41]:

$$V_{ij} = \beta_0 + \beta_1 X_{ijl} + \ldots\ldots\ldots + \beta_n X_{ijn} \tag{3}$$

where X is the attribute vector of the hypothetically designed improved EWS, β_o denotes alternative specific constant (ASC), capturing the effects of unobserved factors not included in attributes [37], and $\beta_1 \ldots\ldots \beta_n$ denote coefficients of warning attributes.

The CL is one of the more widely used techniques to estimate respondents' attribute-specific WTP within a CE framework. The major assumptions are: CE holds the Independence from Irrelevant Alternatives (IIA) property and homogeneous preferences toward alternatives across the respondents. The IIA implies that the inclusion or removal of any alternative from choice set *C* does not affect the relative probabilities of choosing two alternatives. But in practice, we often encounter the violation of IIA properties yielding the biased results [37,42]. In addition, the homogeneous

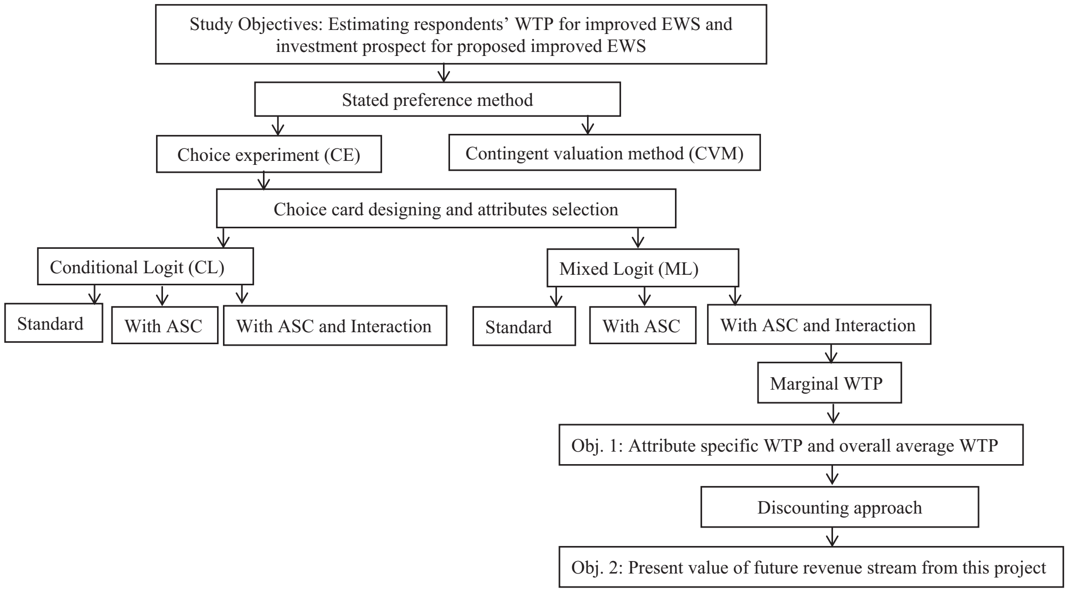


Fig. 1. Flow of methodology.

preference is often violated. These issues pose three significant challenges for CL model: (1) this model is unlikely to capture unobserved preference heterogeneity, (2) it does not allow a panel framework to offer a series of responses for a single respondent, and (3) it is not flexible in extracting the assumptions of independence of irrelevant alternatives (IIA) [62,63]. Greene [43] suggests that introducing interaction terms of attributes with socio-economic variables in the CL model would capture respondents' heterogeneous preferences toward different or improved alternatives. Thus, taking interaction terms would enhance the accuracy and reliability of estimates. On the other hand, inclusion of socio-economic variables as control variables would help to reduce the consequence of IIA violation, as these characteristics account for a substantial portion of variation in the respondents' preference of improved alternatives through increasing the deterministic components of utility and reducing the influence of stochastic components [42]:

$$V_{ij} = \beta_0 + \beta_1 X_{ijl} + \ldots\ldots\ldots + \beta_n X_{ijn} + \delta_1 X_{ijl} S_{il} + \ldots\ldots \delta_l X_{ijn} S_{im} \quad (4)$$

where, m is the number of respondent -specific socioeconomic characteristics, and S denotes the vector of these characteristics; while $\delta_1 \ldots \delta_l$ denotes the l-dimensional matrix of coefficients of interaction terms.

In response to the shortcomings of CL, a Mixed Logit (ML) model is developed and widely used to explore their preference and estimate their WTP to hypothetically improved alternatives. This model, by its derivation, relaxes IIA and homogeneous preference assumptions pertinent to CL. It further overcomes three potential shortcomings of other logit models: (1) allowing random choice variation, (2) unrestricted substitution, and (3) controlling correlation among unobserved factors over time [44]. For these reasons, the ML model is widely accepted as the state-of-art discrete choice model for estimating respondents' WTP under the CE framework [45]. It is computationally simple, straightforward, and can approximate any random utility model. Thus, in this study, we utilized a Mixed Logit (ML) model [64] to overcome the challenges presented. For assessing the effects of observed heterogeneity, estimations in both the CL and ML models in three stages – the standard model, modelling with Alternative Specific Constant (ASC), and modelling with interactions – were used. A statistical software known as Stata (Version 13) was used to analyze the data in this sudy.

In this study, six logit models were used where the four attributes namely: (1) precise time of cyclone landfall with possible impacts; (2) radio forecast frequency; (3) voice message in local dialect over mobile phones; and (4) bid price were taken into consideration. In addition, socio-economic characteristics such as construction materials of house, the age of the head of the household, and the number of vulnerable people within the household are multiplied with attributes in the extended model in order to capture respondents' heterogeneous behavior toward preferences. Landfall time,[2] radio forecast frequency,[3] voice message,[4] and the construction materials[5] of homes were set as categorical dummies; while the service price, together with the age and number of vulnerable people at household were continuous. Preference was measured as the outcome variable, which is a dichotomous dummy variable (Status quo = 0, Improved level = 1). Of these six logit models, three models are estimated as conditional logit (CL) models and three models are estimated as mixed logit (ML) models. Within each of CL and ML models, the first model was a standard model (without ASC), second model included ASC in order to capture the effect of unobserved factors not included in the attribute vector, and the third model was the extended model with interaction terms in order to deal with households' heterogeneous preferences [37]. In this study, ASC takes value 1 if hypothetically improved levels were chosen and 0 for otherwise.

3.2. Administering the choice experiment

The designing of a CE considers a process of four consecutive steps: (1) attributes identification and selection; (2) choice card design; (3) questionnaire design; and (4) sampling procedure.

3.2.1. Attributes identification and selection

Identification and selection of attributes is a crucial process in a CE as the selected attributes affect respondents' preferences. This process involved an in-depth review of relevant literature at the first stage for identification of a list of attributes [for detail see 5,46–51]. The list was then shared with 15 local/regional disaster managers and practitioners (e.g. CPP volunteers, local and regional experts, GO and NGO representatives) in order to seek their opinions, based on their experience of local/regional disaster management activities in cyclone-prone coastal Bangladesh. In addition, six Focus Group Discussions (FGDs) were carried out to narrow down the attribute list. Participants from heterogeneous occupations and

[2] Before 8 h/After 12 h = 0; Before 5 h/After 7 h = 1; Before 4 h/After 6 h = 2; Before 2 h/After 4 h = 3.

[3] 5 Times a day = 0; 8 Times a day = 1; 12 Times a day = 2; 24 Times a day = 3.

[4] No call = 0; 4 Times a day = 1; 8 Times a day = 2; 18 Times a day = 3.

[5] Bamboo, straw and mud = 0; tin and mud = 1; tin and concrete = 2; full concrete = 3, others = 4.

direct victims of tropical cyclone Sidr (2007) and Aila (2009) participated in the discussion. Six attributes were selected on basis of opinions from experts and FGD-participants. Four pilot surveys were performed to check the appropriateness of the selected attributes and finally four attributes were chosen. These attributes, with their levels, are presented in an example of choice card used in this study in Table 1. As the people at risk pondered an improved EWS, accuracy of the forecast information along with likely impact seemed to be the most important issue and, therefore, they were concerned about the timing of cyclone's landfall [52]. Pilot survey respondents stated that they would not only like information regarding a cyclone's projected landfall time, but also prefer information on the likely impacts of the imminent hazard. The attribute of accuracy with likely impacts was presented through proposed improvement levels from 1 to 3, compared to the current condition (*status quo*). These improvement levels were chosen in light of experts' opinions and feedback from pilot surveys.

3.2.2. Choice card design

Feedback from expert opinions, FGDs, and those taking part in pilot surveys were sequentially incorporated into the final design of the CE. The CE reported in this study started with reviewing relevant attributes, together with meteorological features and levels that were used in previous studies [34,53–55]. Once the attributes and levels were selected - after performing literature review, expert opinion, and pilot-survey - an orthogonal choice task design was prepared to minimize correlation among the attribute levels in choice tasks, which resulted in ($3^4=$) 81 choice tasks. To reduce the cognitive burden on sampled respondents, 24 out of 81 choice tasks were selected by discarding the overlapping, repetitive, and dominant choices. These 24 choice tasks were then distilled to six choice cards featuring varying combinations of choice tasks (see example in Table 1). Each respondent was asked to choose randomly any of the six cards and indicate their preference of proposed improvement levels versus retaining the *status quo*. This *status quo* option was the same for all choice tasks.

We designed and proposed an improved cyclone EWS based on three specific improvement levels over *status quo* service attributes. These improvement levels consist of four attributes: (1) Enhanced accuracy of cyclone landfall (i.e., precise landfall time of the cyclone) with possible impacts; (2) increased number of updates a day via radio; (3) voice messaging advisories in local dialects via mobile phones; and (4) a bidding price (i.e. cost). The accuracy of a cyclone's landfall information, together with likely impacts, appears to be the most crucial feature (i.e. attribute) and innovation for the proposed improvement in cyclone EWS. In line with the suggestions by Comprehensive Disaster Management Programme (CDMP) (phase-II) and Deltares, Government of Bangladesh has made significant investment in improved cyclone early warning services over the last decade [56]. As a result, Interactive Voice Response (IVR) and Voice Message Broadcast (VMB) are presently being practiced in Bangladesh as dissemination channels [23,56,57]. Considering this scenario, the proposed structure of accuracy with the likely impact attribute in this study can be considered as a realistic model.

Interviewers presented the respondents with choice cards indicating improvement scenarios of EWS with respective budget constraints. These cards enabled the respondents to become familiar with the individual choice tasks. In this case, three samples of choice cards were shown to respondents prior to their final selection from six choice tasks. Considering the challenge of *anchoring effect* [58] that might affect estimates of WTP, we set three different price levels for each examples of improvement. We acknowledged that the order of improvement levels of choice tasks shown to the respondents might affect their choice outcomes [59]. To address this challenge of *ordering effect* [60], we randomly showed six choice cards to the respondents from which they selected choice tasks, we ensured that the same choice cards were not presented to two consecutive respondents. We collected information on respondents' different attitudinal parameters, not only to unveil factors affecting WTP for improved EWS in coastal Bangladesh but also to assess the investment prospect for the said improvement. For this, we incorporated a cost attribute or a payment mechanism in the choice cards. We designed the payment mechanism as a biannual mandatory payment via mobile phone, a common payment method currently used in Bangladesh. The choice was based on mobile-phone connection density (nearly 87% of the population uses mobile phones) [23]. To the best of the authors' knowledge, the proposed payment mechanism has not previously been used in Bangladesh to purchase EWS.

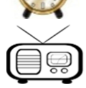
3.2.3. Questionnaire design, sampling procedure, data collection, and study locations

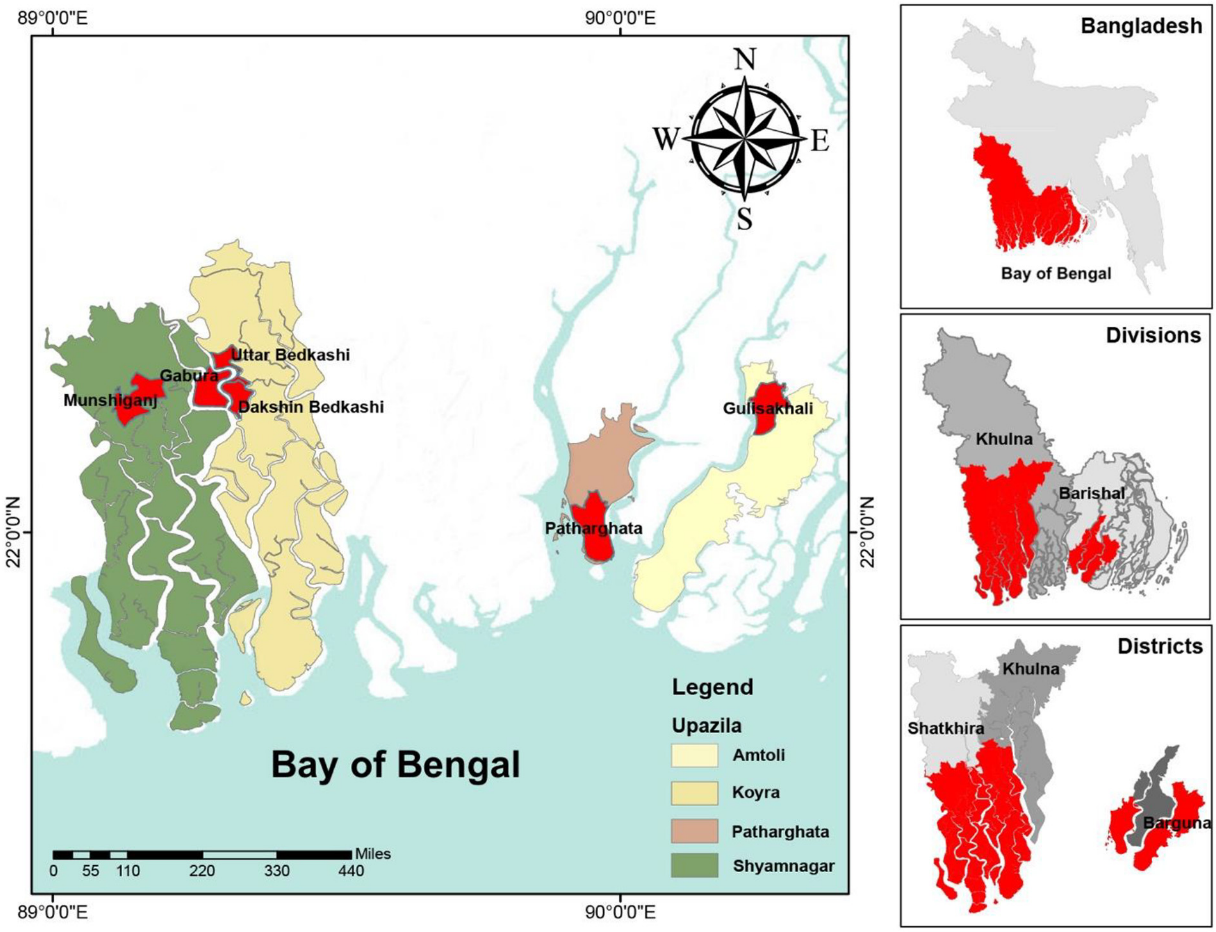
The questionnaire was designed to cover four sections: (1) questions on respondents' socio-demographic and asset portfolios; (2) information on common hazards, their magnitude, frequency, and patterns experienced by the respondents; (3) issues of the existing early warning services; and (4) choice cards.

Questions were selected by- (1) reviewing the relevant literature; (2) face to face discussions with 15 local and regional disaster experts (both managers and practitioners); and (3) six FGDs where participants were mostly the victims of previous cyclones. Having accomplished these three consecutive processes, a total of 63 questions were finally selected for the four sections of the questionnaire. The questionnaire was piloted with 29 respondents in December 2017. The second round, utilizing a modified questionnaire which incorporated a cost adjustment issue, was piloted with 41 respondents in February 2018.

Face to face questionnaire surveys were undertaken with households at risk in the southwestern coastal divisions of Khulna and Barishal between March and May 2018. Areas within these divisions have experienced a significant number of tropical cyclones including cyclone Sidr (in 2007), Aila (in 2009), Mahashen (in 2013), Roanu (in 2016), Mora (in 2017), and Fani (in 2019). For the first stage, we purposely selected three coastal districts (Khulna, Satkhira, and Barguna). In the second stage, we randomly selected six unions (i.e., lowest tier of administration) from the three coastal districts. From each of these six unions, we randomly selected three villages. From these 18 randomly selected villages, we approached 519 households

Table 1
Example of a choice card.
Source: Author's compilation, 2018

Attribute (S)	Imagining	Status Quo	Improvement Level 1	Improvement Level 2	Improvement Level 3
Precise time of cyclone landfall with possible impacts		Before 10 h/after 12 h (no impact is presented)	Before 5 h/after 7 h (with possible impact)	Before 4 h/after 6 h (with possible impact)	Before 2 h/after 4 h (with possible impact)
Radio Forecast		5 Times a day	8 Times a day	12 Times a day	24 Times a day
Voice Message in Local Dialects		None	4 Times a day	8 Times a day	12 Times a day
Bidding Price		0	BDT 350 (US$ 4.17)	BDT 700 (US$ 8.33)	BDT 1000 (US$ 11.91)



Map 1. Geographical locations of the survey areas.
Source: [71]

for face to face surveys and completion of the choice experiment, asking respondents whether they would like to pay for an improved EWS. Of these, 146 household respondents (almost 28%) replied negatively. Among these 146 households, 29 households opined that proposed improvement intervention was not their concern and should be financed by the Government, and thus they were not interested in paying. This was not dependent on whether they could afford to pay. Thus, 29 households, or 5.6% of the 519 selected, were considered as protest bidders. However, 117 of 146 households were interested in paying for the EWS improvement program, but did not have sufficient income to cover the costs involved. We therefore considered response of these 117 households as valid zero (i.e., their answer to question of availing improved EWS was 'no').

Applying the systematic random procedure from Uttar and Dakshin–Bedkashi union (in Koyra upazila of Khulna district), Munshigonj and Gabura union (in Shyamnagar upazila of Satkhira district), and Patharghata and Gulisakhali (in Pathaghata upazila of Barguna district) (see Map 1 for detail of study locations); 490 households were selected for this study. While performing the systematic random selection, at least two roads connected with the Central Business Point of a village were chosen. Every twelfth household on those roads was approached for a face to face interview. The survey team comprised of post-graduate and undergraduate university students, who were trained for two weeks, with a particular focus on the field techniques required to conduct choice experiments.

Table 2
Summary statistics of major socio-economic characteristics of sample households.
Source: Field survey, 2018

Variables	N	Mean	Std. dev.	Min	Max
Age	490	39.24	12.42	18	75
Household size	490	5.31	1.84	1	22
Schooling years	490	4.94	4.37	0	18
Monthly income	490	8426.94	5361.46	1000	50,000
Number of earning member	490	1.41	0.68	1	6
Number of vulnerable people at house[a]	490	2.01	1.22	0	7

[a] Vulnerable people are counted as 'the total number of older adults (65+ years), children (below 17 years), and member(s) with disabilities' within the household.

4. Results

4.1. Socioeconomic profile of the respondents

Table 2 presents the dominant socioeconomic characteristics of respondent-households in this study. The majority (78%) of the respondents were male. The age pattern suggests respondents have experienced the major changes in climatic parameters over the last four decades. Average household size was found to be 5.31 (±1.84) persons, which is slightly higher than the national average (4.06 persons) [61]. Literacy level revealed that respondents had a poor educational status and on average, had completed less than five years of academic schooling. Literacy levels further indicated a high degree of disparity in schooling as Table 2 indicates nearly equal values for both mean and standard deviation. The income distribution of sampled households indicated a high degree of disparity, as the standard deviation presenting a substantial value, equal to 63.62% of the average income. That disparity is reflected in the poverty[6] status of these respondents, which showed that nearly 56% of respondents were living in

[6] The World Bank defines extreme poverty as living on less than US$1.90 a day (PPP), and moderate poverty as less than $3.10 a day [75].

extreme or moderate poverty. Likewise, 73% of the respondents were living in weakly-built structures comprising of bamboo, light materials, and mud. Only 40% of respondents owned more than the average land size of 0.452 (±1.23) acres. In case of utility services, findings suggest >85% of sampled households had access to pure drinking water and electricity, while only 63% used sanitary latrines. On average, 27% household members were primary earners, thus implying a relatively high dependency ratio. The findings from Table 2 suggest that each household, on average, had nearly 38% vulnerable members. Meanwhile, 91% of respondents reported that at least one mobile phone connection was owned within their households. It should be noted that these respondent households incurred an average economic loss of BDT 83,698 (≈US$ 996) in last three years due to natural hazards.

4.2. Econometric estimation

Table 3 presents the econometric results of six logit models, where three models are estimated as conditional logit (CL) models and three models are estimated as mixed logit (ML) models. The CL standard model in Table 3 suggest coefficients of all attributes are positive and statistically significant at 1% level. These signs of coefficients are as expected and imply an improvement on attributes (precise time of cyclone landfall with possible impact, more frequent radio forecasts per day, and voice messages in local dialect) of EW affects its demand positively. In addition, the results revealed a statistically significant negative association with bidding price, which is consistent with conventional demand theory. An exogenous increase in price, holding other attributes constant, would shrink respondents' demand for improved EWS. On the other hand, results from the second CL model with ASC and third model with ASC along with socio-economic interactions in Table 3 exhibit that ASC is positive, though not statistically significant. This implies that the respondents are, on average, more interested in improved early warning forecasting scenarios over the *status quo*. Three out of nine interacted terms between attributes and socio-economic features in the third CL extended model exhibit significant association with the respondents' preference toward proposed EWS improvements. The third CL extended model was shown to be more appropriate than the other CL models, as respondents' socio-economic features such as age and construction material of houses for example, control their heterogeneity in preferences toward improved EWS.

Similar results were obtained from the corresponding three ML models. However, estimates from the ML models were found to be more efficient and precise than those of CL models. This was due to corresponding log-likelihood values from ML models, which were almost half of those values from CL models. Similarly to the CL models, in all ML models all attributes imply results with expected sign and at 1% level of significance (except radio update frequency showing significance at 5% for a simple and interactive model, with no significance for the model with ASC). In the second and third ML models, ASC indicated a positive value and inputting interaction terms in the third ML model exhibited more robust results. In this instance, five out of nine interactions were found to be statistically significant. This implies socioeconomic feature-controlled respondents' heterogeneity in preference toward EWS at a greater scale in ML than that in CL.

Additionally, for every increment from the lower level to immediate upper level, all attributes- i.e., landfall with possible impacts, radio forecast frequency a day, and voice messaging - positively and significantly affected

Table 3
Results of estimated models for improved early warning service.

Conditional logit (CL)				Mixed logit (ML)					
Variables	Standard model	Model with ASC	Model with interaction	Standard model		Model with ASC		Model with interaction	
	Mean	Mean	Mean	Mean	SD	Mean	SD	Mean	SD
ASC		0.134	0.149			27.543	−1.615	45.421	8.421
		(0.182)	(0.183)			(670.695)	(578.361)	(697,511.045)	(408,981.267)
Landfall time	1.071***	1.072***	1.083***	0.472***	1.803***	0.452***	1.814***	1.218***	0.890***
	(0.070)	(0.070)	(0.188)	(0.134)	(0.117)	(0.144)	(0.111)	(0.318)	(0.086)
Radio forecast frequency	0.543***	0.542***	0.742***	0.180**	0.189	0.155	0.250	0.480**	−0.113*
	(0.066)	(0.066)	(0.192)	(0.091)	(0.203)	(0.094)	(0.180)	(0.227)	(0.062)
Voice message in local dialect over mobile phone	0.627***	0.626***	0.514**	1.153***	0.080	1.167***	0.020	0.858***	0.120
	(0.083)	(0.083)	(0.226)	(0.105)	(0.096)	(0.106)	(0.120)	(0.252)	(0.077)
Price	−0.009***	−0.009***	−0.009***	−0.009***		−0.009***		−0.009***	
	(0.001)	(0.001)	(0.001)	(0.001)		(0.001)		(0.001)	
Lfa			−0.002					−0.018**	0.033***
			(0.004)					(0.007)	(0.003)
Ra			−0.010**					−0.012**	0.001
			(0.004)					(0.005)	(0.002)
Cage			0.006					0.009*	−0.000
			(0.005)					(0.005)	(0.002)
Lfvp			−0.038					−0.129	−0.431***
			(0.041)					(0.079)	(0.043)
Rvp			0.034					−0.013	−0.103***
			(0.042)					(0.053)	(0.025)
Cvp			−0.053					0.009	−0.024
			(0.049)					(0.055)	(0.026)
Lfm			0.141**					0.258**	0.076
			(0.066)					(0.117)	(0.074)
Rm			0.101					0.157*	0.062
			(0.067)					(0.083)	(0.082)
Cm			0.004					−0.080	0.077
			(0.079)					(0.089)	(0.049)
Observations:11760 (for 490 respondents)									
Log-likelihood	−5204.33	−5204.05	−5138.22	−2710.59		−2695.27		−2671.46	
Prob > chi2	0.0000	0.0000	0.0000	0.0000		0.0000		0.0000	

Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
SD = standard deviation; Landfall = expected time of cyclone land fall; lfa = landfall × age, ra = radio × age, cage = voice call × age; lvfp = landfall × number of vulnerable people at household, rvp = radio × number of vulnerable people at household, cvp = voice call × number of vulnerable people at household; lfm = landfall × main construction material of house, rm = radio × main construction material of house, cm = voice call × main construction material of house.

Table 4
Marginal WTP estimation (in BDT).
Source: Field survey, 2018

Attributes	CL model			ML model		
	Standard model	Model with ASC	Model with interaction	Standard model	Model with ASC	Model with interaction
Expected time of cyclone landfall with possible impacts	117.29	117.39	130.34	50.54	48.32	142.25
Lower bound estimate	106.75	106.84	67.48	25.17	20.89	33.70
Upper bound estimate	127.82	127.93	193.20	75.90	75.76	250.81
Radio forecast frequency	59.39	59.33	95.42	19.25	16.57	65.53
Lower bound estimate	48.33	48.25	30.21	1.57	−2.06	−10.55
Upper bound estimate	70.46	70.40	160.63	36.93	35.21	141.61
Voice message	68.68	68.60	51.86	123.53	124.76	85.36
Lower bound estimate	55.27	55.17	−24.14	109.86	109.86	3.67
Upper bound estimate	82.09	82.02	127.86	137.21	137.21	167.04

respondents' preferences for improved EWS. In addition, age of the respondent had a significant impact on the delivery preference for improved EWS. Interactions of age with landfall and radio forecast exhibit negative impacts on the preference while interaction with voice message has positive impacts. These findings suggest- adult members in households are less interested in frequent radio updates and precise timings of cyclone landfall, instead they are more interested to receive frequent voice messages of warnings (over mobile phone). The underlying facts of such findings imply the adults in households are generally engaged in earning a living and therefore, they have less time to listen to radio. As they carry mobile phones, they can easily receive and digest information from voice messaging. Meanwhile, older adults are familiar and more experienced with cyclone events and thus can predict the likelihood of magnitude of cyclones by observing the natural signs. As a result, they prefer frequent radio updates and precise cyclone landfall time more and voice message less.

4.3. Willingness to pay (WTP) estimations

Marginal WTP per household for improvements in the cyclone EWS for the coastal area of Bangladesh is reported in Table 4. Both CL and ML model estimates are presented in Table 4, along with the upper and lower bound results.

As anticipated, at-risk coastal individuals have a positive marginal WTP for improved attributes of EWS. The results of the CL model in Table 4 suggest sampled respondents exhibited highest marginal WTP for precise time of cyclone landfall with possible impacts, which is BDT 117 (≈US$ 1.39[7]) more with each level of improvement with respect to the *status quo*. The model with ASC exhibits almost identical WTP, while the model with interaction exhibits slightly higher WTP for each improvement level, which is BDT 130 (≈US$ 1.55). Again, for the same attribute, the first two ML model exhibit lower WTPs for each improvement level (see Table 4), however, the third model (ML with ASC and interaction terms) exhibits higher WTP for each level of improvement, which is BDT 142 for landfall attributes (≈US$ 1.69).

The next higher marginal WTP was obtained for voice messaging in local dialects, which is not currently delivered as an early warning. With respect to the *status quo*, sampled respondents' marginal WTP is BDT 69 (≈US $ 0.82) for each improved level of voice messaging was almost identical for the first and second models of CL estimates (BDT 69 or US$ 0.82), though the third model exhibited a lower value of BDT 51 (≈US$ 0.62). ML estimates exhibited model with ASC (i.e., second model) and interaction (model with ASC) compute WTP of BDT 125 and BDT 85 (≈US$ 1.01) for every increment in lower to immediate upper level, respectively.

Among the improvement attributes, the least marginal WTP was obtained for radio forecast. Standard CL estimates suggest that sampled respondents exhibit a marginal WTP of BDT 59 (≈US$ 0.70), while the interaction model shows a marginal WTP of BDT 95 (≈US$1.13). Among the ML model estimates, the interaction model indicated comparatively higher marginal WTP of BDT 65.5 (≈US$ 0.78) for every increment in lower to immediate upper level.

The average WTP for improved EWS was calculated (based on the interaction part of ML model in Table 4) and is presented in Table 5. The result suggest respondents were interested to pay, at mean level attributes, BDT 468 (≈US$ 5.57) a year for availing improved EWS in two instalments, as proposed in the study choice cards. The average yearly income of sampled respondents was calculated to be BDT 101,124 (≈US$ 1204) implying total WTP for improved EWS is about 0.46% of their annual income. This empirical finding is consistent with results from the study by Lazo et al. [34] and Nguyen et al. [15]. Average WTP of a household for improvements in cyclone warning services in Vietnam is reported to be some 0.19–0.32% of mean household annual income [15], while Lazo et al. [34] estimated that, for the United States, which is around 0.024–0.045%. Meanwhile, Anaman et al. [65] estimated WTP for Australian households at around 0.072% of annual income. The reported percentages are therefore shown to be reasonable for individual countries, as income level differ between developed and developing countries.

5. Discussion on WTP, welfare gain, and policy recommendations

Based on the third model of ML presented in Table 4, an assessment of the investment prospects for improved EWS in coastal Bangladesh was undertaken. In this scenario, we assume, on the basis of a study by Dasgupta et al. [21] and Bangladesh Bureau of Statistics (BBS) [66], the number of vulnerable people exposed along coastal Bangladesh would be 6.03 million by year 2030, due to the impact of extreme climatic events. Considering this scenario, our study has estimated a prospective investment plan for improvement of the EWS. Table 6 presents the annual revenue stream derived out of the payment for the improved cyclone EWS, using the average WTP for the mean level of improvement. The existing calculation is performed only for the assumed vulnerable population, without any impact of climate change.

Results from Table 6 reveal an annual revenue generated by implementation of the improvement program is approximately BDT 309.04 million (≈US$ 3.7 million). Assuming the project would at least run for 10 years,

Table 5
Average WTP estimation.
Source: Field survey, 2018

Attributes	Average WTP[a] at mean attribute level (in BDT)
Expected time of cyclone landfall with possible impacts	224.75
Radio forecast frequency	108.77
Voice message	134.86
Total	468.37

[a] Average WTP = Marginal WTP(mean value of attribute-value of status quo).

[7] In this study US$ 1 = BDT 84 is considered for all estimations.

Table 6
Annual revenue stream for improved early warning system (without climate change).
Source: Field survey, 2018

WTP (in BDT)	Number of vulnerable people	Number of household[a]	Household willing to pay for improvement[b]	Annual revenue[c] (in BDT)	Annual revenue[d] (in US$)
468	6,034,200	1,138,528	660,346	309,042,040	3,646,944

[a] Number of people × average number of household derived by the study.
[b] Number of household × household willing to pay for the improvement.
[c] Household Willing to Pay for Improvement × WTP.
[d] Annual Revenue (in BDT)/US dollar to BDT exchange rate.

the estimated future cumulative revenue would be BDT 1.881 billion (≈US $ 22.39 million) as presented in Table 7.

Major findings suggest the estimated average WTP for a household is BDT 468 (≈US$ 5.57) per year in coastal Bangladesh. Out of the said amount, a household would like to spend nearly 48% (BDT 224.75 (≈US $ 2.68)) to know the precise time of a cyclone's landfall and its possible impacts, 23% (BDT 108.77 (≈US$ 1.29)) for increasing frequency of radio forecasts, and 28.79% (BDT 134.86 (≈US$ 1.61)) for forecast voice messaging in their local dialect (see detail in Table 5). This estimate of average WTP has been performed assuming no impact due to climate change. Considering this scenario, the aggregate WTP estimated for 1.138 million vulnerable households living in the exposed coastal areas of Bangladesh is approximately BDT 309.04 million (≈US$ 3.7 million) a year. This estimated WTP is the minimal amount revenue to be considered for an investment prospect, as the estimation has been performed by considering scenario of no climate change impact and for only the exposed coastal population. In reality, the adverse effects of climate change are visible and in any cyclone at least>1.138 million households would be affected in both exposed and interior coastal Bangladesh. Hence, an investment in EWS improvement appears to be highly lucrative and economically sustainable. A decade-long cumulative revenue generation projection exhibits an amount of BDT 1.881 billion (≈US$ 22.39 million) at a 5% discount (see Table 7). Considering this scenario, investment in improving EWS can be considered as a 'no regret' approach toward managing the impacts of extreme climate events and disaster preparedness.

Based on the findings presented in the above paragraph, we can summarize the following major findings from this study:

- Respondent households at risk exhibited a general preference for improved attributes of cyclone early warning implying they have positive demand for improved EWS.
- For the improved EWS, their average WTP was estimated BDT 468 (≈US $ 5.57) per year.
- Out of the said WTP, respondent households were ready to pay nearly BDT 225, BDT 108, and BDT 134 for improvement in accuracy of the forecast along with possible impacts, for increasing frequency of radio forecast a day, and for receiving voice message in local dialect in their mobile phones; respectively.
- An investment prospect in improvement of EWS in terms of different attributes for a reasonable time frame exhibits a significant pay-back. This implies such investment would be a 'no regret' attempt over time.

Table 7
Revenue stream for improved early warning system for 10 years (without climate change).
Source: Field survey, 2018

Present value (in million US$) at different discounting rate				
Discount rate	5%		10%	
Year	BDT (in billion)	US$ (in million)	BDT (in billion)	US$ (in million)
1[a]				
2	0.556	6.62	0.507	6.03
3	0.794	9.45	0.691	8.22
4	1.008	12.00	0.837	9.96
5	1.2	14.29	0.951	11.32
6	1.372	16.33	1.037	12.35
7	1.524	18.14	1.1	13.10
8	1.659	19.75	1.143	13.61
9	1.777	21.16	1.1693	13.92
10	1.881	22.39	1.181	14.06

[a] In year 1, the initial annual stream of revenue is estimated BDT 0.306 billion (≈US$ 3.65 million).

Major findings of this study are consistent with those from previous studies by Nguyen et al., 2013 [15] and Nguyen and Robinson [83] on issues of accuracy of the imminent cyclone-hazard's information together with availability of the said information via mobile phones and radio. Besides, finding suggesting people with higher income tend to have a higher WTP for improved forecasts is also consistent with study finding by Lazo et al. 2010 [34]. Likewise this study, none of the previous studies took the impact-based forecasting for preparing choice cards and investment prospect for improving EWS into account.

Summary of major empirical findings of this study suggest improvement in three specific issues; accuracy in a cyclone's landfall time with possible impacts, increased weather updates via radio, and voice messaging in local dialects. These facts should spur the desire for increased efficiency in forecasting (with possible impacts), preparation and warning dissemination. BMD may steer both of these efficiencies. Against this backdrop, we propose four policy recommendations:

(1) Enhance observation systems and modelling capabilities. BMD requires an establishment of new and updated observatories. This includes new Radio Sonde[8] stations for upper-air observations and storm gauges to record storm surge height. Introduce an advanced ensemble probabilistic modelling (i.e. CLIPER5[9] and ECMWF[10] models [70]) to predict cyclone pathways, reducing the error in cyclone landfall and intensity forecasts. The cyclone forecasts should include coastal inundation. The existing coastal inundation forecasting model could be enhanced.
(2) Generate 'Impacts-based' forecasting to translate technical knowledge into relevant local information, and thus create more actionable warnings. This forecasting technique will focus on the hazard impacts, and provide both the likely impact and the worst-case scenario to help people understand the severity of the cyclone. Impacts-based forecasting can strongly aid in the delivery of an effective EWS. Different sectors and stakeholders have varying requirements from an EWS. Therefore, a thorough understanding of these requirements and diversity is essential for the communicating authority. This knowledge will help the authority to tailor the warnings to the receiving stakeholders and ensure effectiveness.
(3) Introduce rapid alert dissemination system using multiple communication systems. Introduce cell broadcasting, bulk SMS and call priority services. For this, BMD needs to work with private telecommunications operators in the country and the Telecommunication Regulatory Commission needs to implement an International Telecommunication Union (ITU)-guided, all disaster phased 'National Emergency Telecommunication Plan (NETP)'.

[8] Balloon-borne instrument platform with radio transmitting capability.
[9] This is a statistics-based Climatology and Persistence model.
[10] Multi-layer global dynamical model by European Center for Medium-range Weather Forecasting.

(4) Test the system regularly. Local governments should run simulated emergency drills for children to become familiar with the required actions and support the early warning systems. If the local areas require, schools should be equipped and prepared to act as cyclone shelters.

For implementing all the recommendations above, the revenue generated from the proposed improvement plan shown in Table 7 can be invested, though the required investment can be higher than the generated amount. Under the circumstances, the Government could invite development partners to invest in improving EWS. For example, since 2017 a project known as Bangladesh Weather and Climate Services Regional Project (BWCSRP) - financed by the World Bank - is in progress aiming the improved weather forecasting and EWS for tropical cyclones [56]. The Government of Bangladesh, along with the Ministries concerned and other relevant stakeholders, may be brought into a common platform aligning with BWCSRP. This would deliver a sustainable solution to the challenges of implementing the improvement plan. Consequently, Bangladesh would be able to achieve the global target (2022 (g)) of the Sendai Framework [74] in line with SDG's specific goals (3D and 13.3) on EWS [76].

6. Conclusion

Disasters caused by climate change are no longer scientific speculation or hypothesis, they are a certainty. To minimize the damage from these disasters, especially for areas experiencing recurrent tropical cyclones, adaptation measures aligning with disaster preparedness need to be more efficient and effective. An important adaptation option could be the introduction of an improved cyclone EWS, which requires considerable capital investment. Given the need to secure funding and the management challenges, assessment of the economic feasibility could be a pivotal issue in determining and achieving the level of public and private funding required. This study has performed the estimation of willingness to pay (WTP) at household level by applying a CE for improvements in the tropical cyclone EWS for coastal Bangladesh. It incorporates two features- (1) including impact-based forecasting features in designing the choice cards; and (2) preparation and presentation of an investment proposal for a cyclone EWS improvement program.

Results suggest coastal households at risk have showed their willingness to pay for the proposed improved over the existing –EWS. They were ready to pay BDT 468 (≈US$ 5.57) per year, which is equivalent to 0.48% of their annual income. Of this payment, respondent households would like to spend nearly 48%, 23%, and 29% for knowing precise time of cyclone's landfall with possible impact, increasing frequency of radio forecasts, and voice message on forecasting in local dialect; respectively. A decade long investment prospect in improving EWS has showed a cumulative revenue generation of BDT 1.881 billion (≈US$ 22.39 million) at 5% discount rate, which appears to be economically viable and thus can be considered as 'no-regret' approach for improving existing EWS.

With regard to the payment mechanism, households who wish to pay for improved EWS should be given the ability to do so. As Bangladesh currently possesses several financial inclusion services (e.g., bKash, Rocket, UKash etc.), households may use any of the existing services to make payments user-friendly. Each participating household would need to have access to a mobile phone. This does not necessarily need to be a smartphone. Alternatively, payment could be made by sending the required amount to a specific gateway number from the household's own mobile phone.

This study designed and applied CE for estimating WTP for improved EWS for tropical cyclone hazard. As it did not consider other common natural hazards (e.g., flood and drought), there is scope for future studies to consider multi-hazards in the case of WTP estimation for improved warning services. Again, other available methods, such as the single or double bounded methods, can be used for estimating WTP and delivering potential contrast with the results of this study.

Declaration of competing interest

On behalf of all the authors of the paper titled 'Preferences for improved early warning services among coastal communities at risk in cyclone prone south-west region of Bangladesh', I, the undersigned, would like to declare that we have no conflict of interest among us and with others.

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References

[1] IPCC. Chapter 5. Coastal Systems and Low-Lying Areas. Climate Change 2014: Impacts, Adaptation, and Vulnerability; IPCC Working Group II AR5 [Internet] 2014 [cited 2014 15 October]; Available from: https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap5_FINAL.pdf.
[2] WMO. Global Guide to Tropical Cyclone Forecasting. 2017 [cited 2018 10 September]; Available from: https://cyclone.wmo.int//pdf/Global-Guide-to-Tropical-Cyclone-Forecasting.pdf.
[3] Lindell MK, Perry RW. The protective action decision model: theoretical modifications and additional evidence. Risk Anal 2012;32(4):616–32.
[4] Lindell MK, Hwang SN. Households' perceived personal risk and responses in a multihazard environment. Risk Anal 2008;28(2):539–56.
[5] Potter SH, et al. The influence of impact-based severe weather warnings on risk perceptions and intended protective actions. International Journal of Disaster Risk Reduction 2018;30:34–43.
[6] Baker EJ. Hurricane evacuation behavior. Int J Mass Emerg Disasters 1991;9(2): 287–310.
[7] Ahsan MN, et al. A systematic review of the factors affecting the cyclone evacuation decision process in Bangladesh. J Disaster Res 2016;11(4):742–53.
[8] Ahsan, M.N. Disaster preparedness at household and community levels: the case of cyclone prone coastal Bangladesh. 2016 [cited 2019 21 July]; Available from: https://grips.repo.nii.ac.jp/?action=pages_view_main&active_action=repository_view_main_item_detail&item_id=1525&item_no=1&page_id=13&block_id=24.
[9] Letson D, Sutter DS, Lazo JK. Economic value of hurricane forecasts: an overview and research needs. Natural Hazards Review 2007;8(3):78–86.
[10] Lal, P.N., et al., National systems for managing the risks from climate extremes and disasters, in Managing the Risks of extreme events and disasters to advance climate change adaptation, C.B. Field, et al., Editors. 2012, Cambridge University Press: Cambridge, UK, and New York, NY, USA. p. 339–392.
[11] UNDP. Act now, save later. 2012 [cited 2019 21 July]; Available from: https://www.undp.org/content/undp/en/home/presscenter/articles/2012/07/02/act-now-save-later-new-un-social-media-campaign-launched-.html.
[12] Fakhruddin BSHM, Schick L. Benefits of economic assessment of cyclone early warning systems - a case study on Cyclone Evan in Samoa. Progress in Disaster Science 2019;2: 100034.
[13] Krysanova V, et al. Cross-comparison of climate change adaptation strategies across large river basins in Europe, Africa and Asia. Water Resources Management 2010;24 (14):4121–60.
[14] Lazo JK, Chestnut LG. Economic Value of Current an Improved Weather Forecasts in the US Household Sector; 2002 [cited 2019 19 November]; Available from: https://www.wmo.int/pages/prog/amp/pwsp/documents/STORM_Report.pdf.
[15] Nguyen TC, et al. Estimating the value of economic benefits associated with adaptation to climate change in a developing country: a case study of improvements in tropical cyclone warning services. Ecol Econ 2013;86:117–28.
[16] Flierl G, Robinson A. Deadly surges in the bay of Bengal: dynamics and storm-tide tables. Nature 1972;239:213–5.
[17] Neumann, B., et al., Future coastal population growth and exposure to sea-level rise and coastal flooding - a global assessment. PLoS ONE, 2015. 10(3): p. e0118571.
[18] Ahsan MN, et al. Factors affecting the evacuation decisions of coastal households during Cyclone Aila in Bangladesh. Environmental Hazards 2016;15(1):16–42.
[19] GoB. Emergency prepardness plan for cyclone in Bangladesh. April, 2013 [cited 2014 22 February]; Available from: http://kmp.dmic.org.bd/bitstream/handle/123456789/144/Emergency%20Preparedness%20Plan_Cyclone%20Bangladesh%202013.pdf?sequence=1.
[20] Haque CE. Atmospheric hazards preparedness in Bangladesh: a study of warning, adjustments and recovery from the April 1991 Cyclone. Nat Hazards 1997;16(2–3):181–202.
[21] Dasgupta, S., et al. Vulnerability of Bangladesh to cyclones in a changing climate: potential damages and adaptation cost. 2010 [cited 2019 20 July]; Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1596490.
[22] EM-DAT. Top ten natural disasters in Bangladesh. 2016 [cited 2016 3 February]; Available from: http://emdat.be/country_profile/index.html.

[23] Deltares. Mobile services for flood early warning in Bangladesh. 2015 [cited 2018 16 September]; Available from: https://www.deltares.nl/app/uploads/2015/11/Deltares-Mobile-Services-for-Early-Warning-in-Bangladesh-Final-Report_web.pdf.
[24] Haque CE. Climatic hazards warning process in Bangladesh: experience of, and lessons from, the 1991 April cyclone. Environ Manag 1995;19(5):719–34.
[25] Paul BK, Dutt S. Hazard warnings and responses to evacuation orders: the case of Bangladesh's cyclone Sidr. Geogr Rev 2010;100(3):336–55.
[26] GoB. Interactive voice response bassed disaster early warning system saving lives and livelihood. 2018 [cited 2018 11 September]; Available from: https://modmr.gov.bd/site/files/3543b619-be25-4d83-a2f0-38cec3d871cf/IVR-&-SMS-for-Warnings.
[27] BMD. Role of Bangladesh Meteorological Department in DIsaster Risk Reduction in Bangladesh. 2007 [cited 2018 17 September]; Available from: http://www.wmo.int/pages/prog/dra/rap/documents/5-2-Bangladesh-Hussain.pdf.
[28] Daily Star. 92 fishermen missing for 3 days in the Bay. 2018 [cited 2018 17 September]; Available from: https://www.thedailystar.net/country/92-fishermen-missing-3-days-the-bay-of-bengal-trawler-capsize-1610323.
[29] New Age. 20 fishermen missing in Bay. 2018 [cited 2018 17 September]; Available from: http://www.newagebd.net/article/44008/20-fishermen-missing-in-bay.
[30] Roy C, et al. The current cyclone early warning system in Bangladesh: providers' and receivers' views. International Journal of Disaster Risk Reduction 2015;12:285–99.
[31] Afroz R, Hanaki K, Hasegawa-Kurisu K. Willingness to pay for waste management improvement in Dhaka city, Bangladesh. Journal of Environmental Management 2009; 90(1):492–503.
[32] Afroz R, Masud MM. Using a contingent valuation approach for improved solid waste management facility: evidence from Kuala Lumpur, Malaysia. Waste Management 2011;31(4):800–8.
[33] Kouser S, Qaim M. Valuing financial, health, and environmental benefits of Bt cotton in Pakistan. Agricultural Economics 2013;44(3):323–35.
[34] Lazo JK, et al. Household evacuation decision making and the benefits of improved hurricane forecasting: developing a framework for assessment. Weather & Forecasting 2010;25(1):207–19.
[35] Lancaster KJ. A new approach to consumer theory. Journal of political economy 1966; 74(2):132–57.
[36] Hanemann WM. Discrete/continuous models of consumer demand. Econometrica 1984; 52(3):541–61.
[37] Louviere, J.J., D.A. Hensher, and J.D. Swait, Stated choice methods: analysis and applications. 2000: Cambridge university press.
[38] Manski CF. The structure of random utility models. Theory and Decision 1977;8(3): 229–54.
[39] McFadden D. The revealed preferences of a government bureaucracy: empirical evidence. The Bell Journal of Economics 1976;7(1):55–72.
[40] Hanley N, Mourato S, Wright RE. Choice modelling approaches: a superior alternative for environmental valuation? Journal of Economic Surveys 2001;15(3):435–62.
[41] Maddala, G.S., Limited-dependent and qualitative variables in econometrics. 1986: Cambridge university press.
[42] Rolfe J, Bennett J, Louviere J. Choice modelling and its potential application to tropical rainforest preservation. Ecol Econ 2000;35(2):289–302.
[43] Greene WH. Econometric analysis. New York: Pearson Education; 1997.
[44] McFadden D, Train K. Mixed MNL models for discrete response. J Appl Economet 2000; 15(5):447–70.
[45] Greene WH, Hensher DA. A latent class model for discrete choice analysis: contrasts with mixed logit. Transportation Research Part B: Methodological 2003;37(8):681–98.
[46] Anderson-Berry L, et al. Sending a message: how significant events have influenced the warnings landscape in Australia. International Journal of Disaster Risk Reduction 2018; 30:5–17.
[47] Kox T, et al. Towards user-orientated weather warnings. International Journal of Disaster Risk Reduction 2018;30:74–80.
[48] Losee JE, Joslyn S. The need to trust: how features of the forecasted weather influence forecast trust. International Journal of Disaster Risk Reduction 2018;30:95–104.
[49] Morss RE, et al. Is storm surge scary? The influence of hazard, impact, and fear-based messages and individual differences on responses to hurricane risks in the USA. International Journal of Disaster Risk Reduction 2018;30:44–58.
[50] Taylor AL, Kox T, Johnston D. Communicating high impact weather: improving warnings and decision making processes. International Journal of Disaster Risk Reduction 2018;30:1–4.
[51] Casteel MA. An empirical assessment of impact based tornado warnings on shelter in place decisions. International Journal of Disaster Risk Reduction 2018;30:25–33.
[52] Powell MD, Aberson SD. Accuracy of United States tropical cyclone landfall forecasts in the Atlantic Basin (1976–2000). Bull Am Meteorol Soc 2001;82(12):2749–68.
[53] Gunasekera D. Economic issues relating to meteorological provision. Melbourne, Australia: Bureau of Meteorology research centre; 2004.
[54] Morrow BH, Lazo JK. Coastal emergency managers' preferences for storm surge forecast communication. . 2ndJ. Emerg. Manag., 12; 2014; 153–60.
[55] Lazo JK, Waldman DM. Valuing improved hurricane forecasts. Economics Letters 2011; 111(1):43–6.
[56] World Bank. Bangladesh and World Bank sign $113 million to improve weather forecasting and early warning systems. 2017 [cited 2019 18 July]; Available from: https://www.worldbank.org/en/news/press-release/2017/04/05/bangladesh-and-world-bank-sign-113-million-to-improve-weather-forecasting-and-early-warning-systems.
[57] GoB. Interactive Voice Response (IVR) based early warning system in saving lives and livelihood. 2012 [cited 2019 12 June]; Available from: http://khedaparaup.jessore.gov.bd/sites/default/files/files/khedaparaup.jessore.gov.bd/page/5bcbacf9_daed_485e_8b30_3e3c2b1de6e7/e262a492aa74edc1059d72703636eb29.pdf.
[58] Ladenburg J, Olsen SB. Gender-specific starting point bias in choice experiments: evidence from an empirical study. Journal of Environmental Economics and Management 2008;56(3):275–85.
[59] Day B, et al. Ordering effects and choice set awareness in repeat-response stated preference studies. Journal of Environmental Economics and Management 2012;63(1):73–91.
[60] Halvorsen B. Ordering effects in contingent valuation surveys. Environ Resource Econ 1996;8(4):485–99.
[61] BBS. Household Income and Expenditure Survey (HIES) 2005–2016. 2016 [cited 2019 01 August]; Available from: http://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/b343a8b4_956b_45ca_872f_4cf9b2f1a6e0/Comparative%20Matrix%20HIES_fnl.pdf.
[62] Hoyos D. The state of the art of environmental valuation with discrete choice experiments. Ecol Econ 2010;69(8):1595–603.
[63] Hensher DA, Rose JM, Greene WH. Applied choice analysis: a primer. Cambridge, UK: Cambridge University Press; 2005.
[64] Train KE. Discrete choice methods with simulation. Cambridge, UK: Cambridge University Press; 2009.
[65] Anaman KA, et al. Benefits of meteorological services: evidence from recent research in Australia. Meteorological Applications 1998;5(2):103–15.
[66] BBS. ICT use and access by individuals and households Bangladesh 2013. 2015 [cited 2016 11 January]; Available from: http://bbs.gov.bd/WebTestApplication/userfiles/Image/LatestReports/ICTUseAccessSurvey2013.pdf.
[67] The Daily Star. Cyclone Fani to hit Bangladesh tomorrow. 2019 [cited 2019 30 July]; Available from: https://www.thedailystar.net/country/news/cyclone-fani-hit-bangladesh-tomorrow-1737550.
[68] Dhaka Tribune. Relief, as Cyclone Fani croses Bangladesh with no major disaster. 2019 [cited 2019 29 July]; Available from: https://www.dhakatribune.com/bangladesh/nation/2019/05/05/relief-as-cyclone-fani-crosses-bangladesh-with-no-major-disaster.
[69] Rahman M. Impact of human capital on disaster preparedness in the Coastal Bangladesh. Economics discipline. Khulna: Khulna University; 2019.
[70] NOAA. Technical summary of the National Hurricane Center Track and Intensity Models. 2009 [cited 2019 31 July]; Available from: https://www.nhc.noaa.gov/pdf/model_summary_20090724.pdf.
[71] BBS. GIS application tool. 2019 [cited 2019 07 August]; Available from: http://203.112.218.67/bbsdis/
[72] Fakhruddin, B.S.H.M., Lomarda N., and Boylan K. Total warning system for tropical cyclones. 2018 [cited 2019 25 August]; Available from: https://www.pacificmet.net/sites/default/files/inline-files/documents/PMC%205_%20WP%2016.1%20Att.3%20Total%20Warning%20System%20for%20Tropical%20Cyclone.pdf.
[73] Fakhruddin, B.S.H.M. Risk communication for cyclone early warning– do people get the message, and understand what it means for them? 2018 [cited 2019 25 August]; Available from: https://hepex.irstea.fr/risk-communication-for-cyclone-early-warning/.
[74] UNISDR. Implementing the Sendai framework to achieve the sustainable development goals. 2017 [cited 2019 29 August]; Available from: https://www.unisdr.org/files/50438_implementingthesendaiframeworktoach.pdf.
[75] World Bank. Understanding poverty. 2016 [cited 2019 September 04]; Available from: https://www.worldbank.org/en/topic/poverty/overview.
[76] UNISDR. The Sendai Seven Campaign- 7 targets, 7 years (2016–2022). 2016 [cited 2019 03 September]; Available from: https://www.preventionweb.net/files/54917_iddr2017conceptnote.pdf.
[77] Choudhury AM. Managing Natural Disasters in Bangladesh. Meet on sustainable development in Bangladesh: achievements, opportunities and challenges at Rio + 10. Dhaka: Bangladesh Unnayan Parishad; 2002.
[78] EM-DAT. Damages due to hydro-meteorological hazards in Bangladesh. 2019 [cited 2019 13 December]; Available from: http://emdat.be/dbase.
[79] The Daily Star. A sigh of relief. 2019 [cited 2019 12 December]; Available from: https://www.thedailystar.net/frontpage/cyclone-fani-sigh-relief-1738873
[80] Saha SK, James H. Reasons for non-compliance with cyclone evacuation orders in Bangladesh. International Journal of Disaster Risk Reduction 2017;21:196–204.
[81] Howell, P. Indigenous early warning indicators of cyclones: potential application in coastal Bangladesh. 2003 [cited 2019 16 December]; Available from: https://www.unisdr.org/files/1529_workingpaper6.pdf.
[82] Paul BK. Factors affecting evacuation behavior: the case of 2007 cyclone Sidr. Bangladesh Professional Geographer 2012;64(3):401–14.
[83] Nguyen TC, Robinson J. Analysing motives behind willingness to pay for improving early warning services for tropical cyclones in Vietnam. Meteorological Applications 2015;22(2):187–97.
[84] Mitchell RC, Carson RT, Carson RT. Using surveys to value public goods: the contingent valuation method. Washington DC: Resources for the Future; 1989.