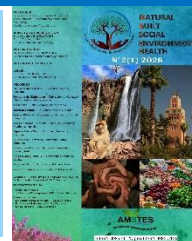


**Natural Built Social Environment Health**

ISSN 3085-461X

www.nbseh.org

Determinants of Household Willingness to Pay for Improved Urban Air Quality: Evidence from Khulna City, Bangladesh

Tanvir Ahmed ^{1a*}, Nure Jannat Arpa ^{1b}, Abdullah Al Zabir ^{2c}

¹ Faculty of Agricultural Economics and Agribusiness Studies, Khulna Agricultural University , Khulna, Bangladesh

² Seed and Horticulture Wing, Bangladesh Agricultural Development Corporation, Dhaka, Bangladesh

^a **ORCID:** 0009-0009-5827-6230; **Email:** tanvirahmedswapnil@gmail.com

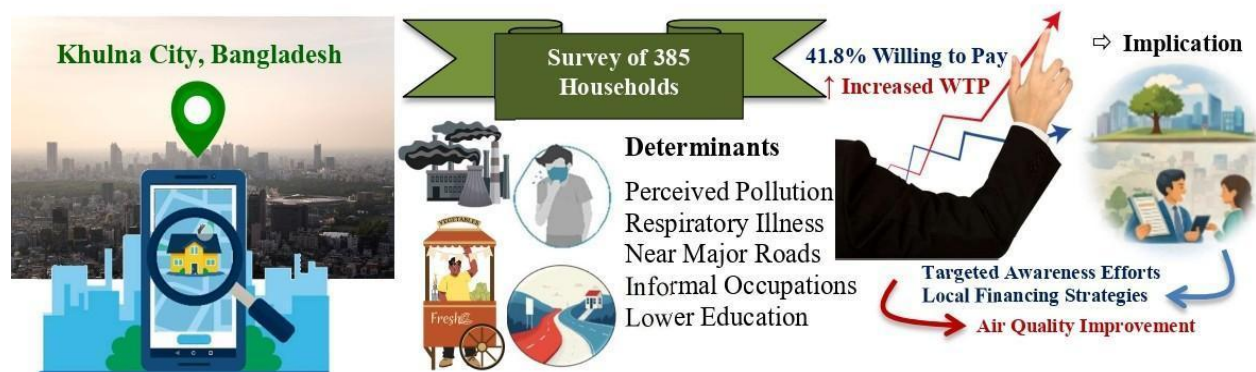
^b **ORCID:** 0009-0003-4183-0529; **Email:** arpa.kau.bd@gmail.com

^c **ORCID:** 0000-0003-2377-7800; **Email:** zabir.sylau@gmail.com

* Corresponding author: Tanvir Ahmed ; Email: tanvirahmedswapnil@gmail.com

Graphical Abstract

This study investigates the determinants of households' willingness to pay (WTP) for improved urban air quality in Khulna City, Bangladesh, based on a survey of 385 households. Results show that perceived air pollution, respiratory illness, residential proximity to major roads, and engagement in informal occupations significantly increase the likelihood of WTP, whereas lower educational attainment reduces it. Income and gender are not significant predictors. The findings highlight the importance of risk perception, health vulnerability, and exposure in shaping environmental valuation behaviour, providing evidence to inform targeted awareness campaigns and locally appropriate air quality financing strategies.



DOI: [10.63095/NBSEH.26.553041](https://doi.org/10.63095/NBSEH.26.553041)

Received: 19 February 2026

Revised: 17 March 2026

Accepted: 26 March 2026

Published online: 07 April 2026

Citation: Ahmed, T., Arpa, N. J., & Al Zabir, A., 2026, Determinants of household willingness to pay for improved urban air quality: Evidence from Khulna City, Bangladesh. *Natural Built Social Environment Health* 2(2), 173-199. <http://www.doi.org/10.63095/NBSEH.26.553041>

Abstract: Air pollution is a major public health and environmental challenge in Bangladesh, with limited evidence on residents' economic valuation of air quality improvements, particularly in secondary cities. This study analyses determinants of households' willingness to pay (WTP) for improved air quality in Khulna City using face-to-face survey data from 385 households. WTP was modelled as a binary outcome with logistic regression. About 41.8% of respondents reported WTP. Perceived air pollution, household respiratory illness, proximity to major roads, and engagement in informal occupations significantly increase WTP, whereas lower educational attainment reduces it. Income and gender are not significant predictors. The model shows acceptable discrimination (ROC–AUC = 0.72). The results highlight the importance of risk perception, health experience, and exposure in shaping environmental valuation behaviour and offer local evidence to inform awareness actions and practical financing strategies for improving urban air quality in Bangladesh.

Keywords: Willingness to Pay (WTP), Air Pollution, Logistic Regression.

Introduction

Air pollution is one of the most serious environmental health threats, contributing substantially to early deaths, long-term illness, and growing health gaps between different social and economic groups. According to the World Health Organization, millions of people die every year from exposure to polluted air, but the risk is not shared equally. People's vulnerability often depends on factors such as income, education, the quality of their housing, and the kind of work they do. Environmental inequality has been highlighted in global public health research [1]. Long-term exposure to fine particulate matter (PM_{2.5}) is associated with cardiovascular disease, chronic obstructive pulmonary disease (COPD), lung cancer, and stroke, and short-term exposure exacerbates respiratory symptoms and reduces productivity [2]. Socially disadvantaged groups face both higher exposure and limited adaptive capacity [3].

The way people respond to air pollution is shaped by what they know and how they perceive the risk. Providing air quality information to the public did not directly lead to protective behavioural changes because awareness must be translated into personal motivation and feasible actions before respondents adjust their activities [4]. Subjective assessments of air quality, such as perceived visibility or odour, often correlate with objective pollution signals and influence stated willingness to pay (WTP) or willingness to accept (WTA) compensation for air-quality changes [5]. These findings suggest that public valuation of cleaner air is not determined solely by income but is shaped by perceived vulnerability, experienced harms, and structural socio-economic conditions [3]. These issues are especially important in South Asia, one of the most heavily polluted regions in the world. Rapid urban growth, rising numbers of vehicles, widespread brick kiln operations, and expanding industrial activity have all contributed to consistently high levels of air pollution in many South Asian cities. Bangladesh has experienced sustained deterioration in air quality over recent years, especially in Dhaka, where multi-year PM_{2.5} assessments document worsening trends and growing health concerns [6]. Seasonal dynamics intensify risks; wintertime measurements reveal dangerously elevated pollutant levels driven by both local emissions and transboundary transport processes [7]. Remote sensing analyses also show spatial heterogeneity in pollutant concentrations across coastal and urban regions of Bangladesh, emphasizing the need for context-specific evidence [1].

Although monitoring studies provide critical diagnostics of pollution levels, effective policy design requires understanding how residents perceive and economically value improvements in air quality. Perception-based research in Bangladesh indicates that urban populations, including residents of Khulna, hold differentiated views regarding seasonal variation, pollution sources, and health consequences [8]. Yet, perception alone does not reveal whether households are WTP. Translating

environmental awareness into economic commitment is little studied in Bangladesh, outside Dhaka, the capital city.

Economic valuation methods, especially contingent valuation and stated-preference approaches, provide a mechanism for quantifying the welfare benefits of non-market goods such as improved air quality. Empirical applications across diverse contexts demonstrate the feasibility and policy relevance of WTP estimation. For example, contingent valuation studies in Thailand, Mexico, and Kenya report positive and policy-relevant WTP for air-quality improvements, often influenced by environmental attitudes, health concerns, and socio-economic characteristics [9,10]. In industrial and mining regions, residents' WTP has been linked to perceived exposure and environmental dissatisfaction, reinforcing the behavioural importance of risk perception [11]. Complementary revealed-preference approaches also demonstrate that clean-air benefits may be capitalized into housing prices, emphasizing the economic value of pollution reduction [10].

Within the broader WTP literature, a consistent empirical finding is that valuation behaviour is multidimensional. Education frequently correlates positively with WTP through enhanced environmental awareness, yet income constraints may limit contribution capacity [4,8]. Perceived pollution severity and personal or household health experience are among the strongest predictors of stated WTP [5]. Exposure conditions such as proximity to major roads or industrial sites can also increase contribution willingness, reflecting heightened vulnerability [11]. Nonetheless, the strength and interaction of these determinants vary across cities and institutional contexts, cautioning against direct transfer of findings between countries or even between metropolitan and secondary cities.

Bangladesh faces an empirical gap at the intersection of measured pollution, perceived risk, and household-level economic valuation, particularly outside Dhaka. Most Bangladesh-focused research concentrates on pollution monitoring and health diagnostics [1,6]. Secondary cities such as Khulna differ from the capital in industrial composition, occupational structures, governance capacity, and population density. These differences may shape exposure patterns, awareness levels, and financial willingness to support environmental interventions. Without localized WTP evidence, policymakers risk designing financing mechanisms or awareness campaigns that omit residents' perceived risks and socio-economic realities.

This study addresses that gap by investigating the determinants of households' willingness to pay for improved urban air quality in Khulna City. Using a structured household survey and binary logistic regression analysis, the research examines how socio-demographic characteristics, perceived pollution, respiratory health experience, occupational exposure, and residential proximity to major roads jointly shape expressed financial commitment. By combining ideas from

environmental risk perception with economic valuation approaches, this study offers context-specific evidence that can help support fairer and more effective air quality management in urban Bangladesh.

Literature Review

Global Burden of Air Pollution and Public Health Implications

Air pollution is one of the most critical environmental and public health challenges worldwide. Long-term exposure to ambient particulate matter (PM_{2.5}) is often linked to increased risks of cardiovascular disease, stroke, chronic obstructive pulmonary disease (COPD), lung cancer, and premature mortality. Systematic reviews and meta-analyses conducted in the Asia-Pacific region have reported a strong exposure–response relationship between ambient PM_{2.5} and all-cause as well as cause-specific mortality [2].

Recent spatial analyses indicate that PM_{2.5} concentrations remain alarmingly high in many South Asian urban centres, posing substantial health risks to exposed populations [12]. The burden of disease attributable to air pollution is not evenly distributed and is concentrated in developing regions where enforcement and regulatory capacity are often weaker. It is important to understand not only the health consequences of pollution but also the ways in which affected populations adjust their economic decisions and behaviours.

Air pollution influences psychological stress and perceived vulnerability, shaping individuals' awareness and behavioural responses [13]. Perceived risk plays a crucial role in linking objective exposure and economic valuation of environmental improvements. Consequently, assessing WTP for cleaner air requires integrating not only epidemiological evidence but also behavioural and perceptual factors.

Air Pollution in South Asia and the Bangladesh Context

South Asia is one of the most densely populated regions in the world. Satellite-based evaluations of nitrogen dioxide (NO₂), sulphur dioxide (SO₂), and aerosol optical depth across South and East Asia demonstrate persistent pollution hotspots in rapidly growing cities [14]. Bangladesh faces severe air pollution from brick kilns, transport emissions, construction activities, and industrial clusters.

Empirical studies in Bangladesh indicate strong associations between perceived air pollution and self-reported health outcomes [15]. Residents in pollution-prone urban areas report high exposure awareness, respiratory symptoms, and concerns about environmental degradation. Additionally,

household air pollution, especially from cooking practices, is an important contributor to overall exposure burdens in both rural and peri-urban settings [16]. The pollution problem in Bangladesh has many forms: urban pollution, traffic-related emissions, industrial sources, and household-level exposures. Perception of pollution risk and personal health experiences can strongly influence individuals' valuation of mitigation measures. Despite increasing evidence of harm, there are few economic valuation studies, particularly in secondary cities such as Khulna.

Theoretical Foundations of Willingness to Pay (WTP)

Willingness to pay (WTP) is a central concept in environmental economics for valuing non-market goods such as air quality. Rooted in welfare economics and random utility theory, WTP measures the monetary amount individuals are willing to sacrifice to obtain environmental improvements or reduce risks.

The contingent valuation method (CVM) has been widely applied to estimate WTP for air quality improvements. For example, contingent valuation techniques have been used to assess WTP for improved air quality among manufacturing workers in China [17], identifying education, income, and exposure levels as key determinants. Similarly, scholars applied valuation methods in Thailand to estimate local demand for improved air quality, demonstrating the importance of satisfaction with current environmental conditions and perceived pollution sources [18].

Methodological studies show that CVM designs should account for hypothetical bias, protest responses, and payment vehicle sensitivity to improve the reliability of estimates [19]. In developing countries, where income constraints and informal employment are prevalent, these methodological considerations become particularly important. Including psychological factors such as risk perception, subjective norms, and environmental attitudes has improved WTP research. This shows that people's WTP is influenced by their beliefs, social influence, and how vulnerable they feel to environmental risk [20].

Determinants of Willingness to Pay for Improved Air Quality

Empirical research consistently identifies several determinants of WTP for air quality improvements:

Socio-demographic factors

Education and income are typically positively associated with WTP, as higher education enhances environmental awareness and income increases financial capacity [17]. Yet, these relationships may vary across different contexts depending on economic constraints and local environmental priorities.

Perception and awareness

Individuals who perceive air pollution as severe or harmful exhibit significantly higher WTP [20]. Information disclosure and air quality alerts can influence behavioural responses, yet perception does not always perfectly align with objective pollution levels.

Health experience

Direct or household-level experience of pollution-related illness increases the valuation of environmental improvements. Studies demonstrate that respondents with respiratory conditions or with family members affected by pollution show stronger WTP [2].

Exposure and residential location

Proximity to major roads or industrial areas has been linked to increased exposure and higher WTP. Spatial exposure studies indicate that individuals residing near traffic corridors or high-emission zones show strong WTP [21].

These determinants often interact. For example, education may strengthen the effect of perception on WTP, and income affects WTP.

Regional Evidence from Asia

Evidence from China, Vietnam, and Thailand provides useful comparative insights for understanding WTP dynamics. Studies in China demonstrate that manufacturing workers and urban residents exhibit significant WTP for improved air quality, particularly when pollution awareness is high [17]. In Vietnam, studies found that respondents preferred measures such as expanding green spaces and promoting cleaner fuels, with WTP influenced by education, income, and time spent in traffic-congested environments [22].

These regional findings suggest that environmental valuation in developing Asian cities is shaped by a combination of exposure intensity, socio-economic capacity, and policy trust. Yet, most existing studies focus on large metropolitan areas. Secondary cities are less studied.

Research Gaps and Justification for the Present Study

Despite growing literature on air pollution valuation, several gaps persist.

First, empirical WTP studies in Bangladesh remain scarce, especially outside Dhaka. Secondary cities such as Khulna may exhibit distinct pollution patterns, occupational structures (including informal employment), and awareness levels, necessitating localized investigation.

Second, despite the increased evidence of harm, few studies integrate the factors now under review.

Third, environmental inequality research suggests that pollution burdens are unevenly distributed [23]. Yet, there is little work on how these inequalities translate into differences in environmental valuation behaviour in Bangladeshi cities.

By focusing on Khulna City, the present study addresses these gaps by examining how socio-demographic characteristics, perceived pollution, respiratory illness, and residential proximity jointly shape WTP for improved air quality. This localized analysis contributes context-specific evidence for designing equitable urban air quality interventions and financing mechanisms.

Existing work highlights the importance of risk perception, health experience, and socio-economic characteristics in shaping WTP for air quality improvements. Nevertheless, most studies focus on metropolitan areas or high-income settings, with limited evidence from secondary cities in South Asia. Moreover, few studies integrate exposure-based vulnerability indicators such as residential proximity and informal occupational exposure within a unified analytical framework. These gaps justify the present study of Khulna City, the geographical urban area, rather than Khulna City Corporation as the administrative or governing authority.

Theoretical Framework

The analytical foundation of this study is grounded in Random Utility Theory (RUT) which posits that individuals make choices by comparing the expected utility derived from alternative states of the world. In the context of environmental quality, improved air conditions generate positive utility through better health, enhanced productivity, and improved quality of life. A respondent's expressed willingness to contribute financially indicates a preference for an improved environmental condition compared to his or her current one.

Environmental risk perception theory suggests that people's awareness of environmental hazards affects how they respond. Individuals who perceive pollution as a serious risk or who have experienced pollution-related health problems are more likely to recognize the cost of environmental degradation and support mitigation efforts. These integrated ideas suggest that socio-demographic factors influence WTP through different levels of awareness and vulnerability, and risk perception and personal health experience more directly shape how people value pollution reduction.

Methods

Study Area and Population

This study was conducted within the administrative boundary of Khulna City. This study was conducted in an urban region characterized by dense population clusters, diverse socio-economic conditions, and varying levels of exposure to air pollution. The findings accurately indicate local perceptions, environmental awareness, and behavioural responses related to air quality, focusing exclusively on Khulna city residents. Since many individuals travel to Khulna for work, trade, or other activities, enumerators verified residency before enrolment to ensure sample integrity. The results reflected the lived experiences of actual city residents.

Sample Size and Sampling Technique

The sample size was determined using Yamane's formula, which is widely applied in social and environmental research to generate statistically reliable samples from finite populations [24]. Using a 95% confidence level and a 5% margin of error yielded a target sample of 385 respondents. Participants were selected using a convenience sampling technique, an approach considered efficient in urban field settings where time, accessibility constraints, and population mobility often challenge the implementation of probabilistic sampling. Although the approach is non-probabilistic, this technique allowed rapid access to diverse respondent groups across different locations within the city.

Sampling Considerations and Limitations

Although the sample size was statistically determined using Yamane's formula, respondents were selected using a convenience sampling approach because of logistical constraints common in dense urban environments. Convenience sampling may introduce selection bias and limit the generalizability of findings as a non-probability sampling method to the broader population of Khulna City.

The estimated coefficients are interpreted as indicative of statistical associations rather than population-level causal effects. Nonetheless, efforts were made to ensure socio-economic diversity across neighbourhoods to improve variability and analytical robustness. Future research employing probability-based sampling designs would strengthen external validity.

Questionnaire Development and Administration

A structured questionnaire was developed based on existing literature on WTP, environmental perception, and socio-demographic determinants. To ensure linguistic clarity and cultural appropriateness, the instrument was translated into Bangla following best practices for survey translation and comprehension enhancement [25]. The questionnaire included sections on socio-demographic characteristics, environmental awareness, health conditions, perceived air quality, residential proximity to pollution sources, and WTP for air quality improvement.

Trained enumerators collected the data via face-to-face interviews. In studies of heterogeneous populations, face-to-face surveys can improve response quality, minimize comprehension errors, and facilitate rapport-building between respondents and interviewers [26]. In a large longitudinal study, rapport between interviewers and respondents was associated with fewer missing responses in face-to-face interviews, improving overall data quality [27].

Willingness to Pay (WTP) Elicitation Approach

A dichotomous choice stated preference question was included in the questionnaire to assess residents' WTP for improved air quality. Respondents were asked whether they would be willing to contribute financially to initiatives for improving air quality in Khulna City. The question was framed in general terms and did not specify a fixed monetary amount.

This approach was taken to capture respondents' expressed support for contributing to air pollution mitigation efforts rather than to estimate a precise monetary valuation. Accordingly, the dependent variable represents a binary indicator of financial willingness (1 = Yes, 0 = No).

Although the survey did not elicit a specific payment amount, the binary WTP measure enables analysis of socio-demographic, environmental, and health-related determinants of contribution willingness. This design is consistent with exploratory valuation studies conducted in developing urban contexts where the primary objective is to understand reasons for financial commitment rather than to compute aggregate economic value.

Data Validation and Quality Assurance

After data collection, a multi-step validation procedure was implemented. This included checking for outliers, inconsistencies, incomplete responses, and logical inconsistencies between variables. Responses were cross-validated against known socio-demographic patterns of the Khulna City population to ensure data set reliability [14]. Only validated records were included in the final analytical dataset.

Variables and Measures

The study incorporated a comprehensive set of socio-demographic, environmental, and health-related variables to understand the determinants of WTP for improved air quality. Table 1 presents the operational definitions, types, and coding scheme for all variables included in the analysis.

In this study, “Corporate” refers to individuals employed in formal private sector organizations in salaried positions, whereas “Business” refers to self-employed individuals or entrepreneurs engaged in their own commercial or trading activities.

Table 1. Variable Definitions and Coding Scheme

Variable Name	Description	Type	Coding
WTP binary	Binary indicator of respondents' expressed financial willingness to contribute to air quality improvement initiatives	Binary (Dependent Variable)	1 = Yes, 0 = No
Age	Age group of respondents	Categorical	Young / Middle / Old
Education	Highest educational attainment	Categorical	Illiterate, Primary, High School, Above High School
Occupation	Primary employment category	Categorical	Informal, Student, Government, Corporate (Private Salaried Workers), Business (Self-Employed)
Income category	Monthly household income category	Categorical	Low, Medium, High
Gender	Respondent's gender	Categorical	Male / Female
Perceived Pollution	Whether respondents perceive air pollution in the area	Binary	1 = Yes, 0 = No
Respiratory illness	Presence of respiratory illness in household	Binary	1 = Yes, 0 = No
Near Road	Residential proximity to major road/high-traffic area	Binary	1 = Near road, 0 = Not near
WTP probability	Modelled probability of WTP (used in simulation, not survey)	Continuous	Values 0–1

Data Analysis

All statistical analyses were conducted using IBM SPSS Statistics 25 software, which was used to perform air quality by quantitative analyses, including regression and multivariate statistical techniques to identify relationships between pollutants and environmental variables [28]. Descriptive statistics were generated to summarize respondent characteristics, followed by inferential analyses to examine relationships between WTP and explanatory variables. Binary logistic regression was applied to identify significant predictors of willingness to pay. Model diagnostics and goodness-of-fit measures were employed to validate the analytical models and ensure the reliability of the findings [29].

Ethical Consideration

Although no formal institutional ethical approval was obtained for this study, all procedures adhered strictly to the core principles outlined in the Declaration of Helsinki, particularly those related to respect for persons, voluntary participation, and the protection of respondent confidentiality. Before each interview, enumerators clearly explained the purpose of the research, the nature of participation, and the respondent's right to decline or withdraw at any stage without any consequences. Only individuals who provided verbal informed consent proceeded with the survey.

No identifying personal information was collected, and all responses were anonymized to ensure privacy and confidentiality. The data were used exclusively for academic research purposes, and participants were assured that their information would not be disclosed to any third party. The study was conducted with careful attention to maintaining the dignity, autonomy, and rights of all respondents, consistent with internationally accepted ethical standards for human-subject research.

Analytical Framework

This study employed a binary logistic regression model, an approach suitable for analysing dichotomous outcomes in environmental economics and consumer valuation research to identify the determinants of residents' WTP for improved air quality. The dependent variable WTP was coded as 1 = Yes and 0 = No, and it indicates whether respondents expressed a positive financial willingness to contribute to air pollution mitigation efforts. Logistic regression models the probability of a positive WTP response through a non-linear logit function. It accommodates both categorical and continuous explanatory variables.

The methodological choice is further supported by a study conducted among urban consumers in Region 02 of the Philippines where binary logistic regression was used to estimate the determinants of consumers' WTP a premium for organic vegetables, revealing significant associations with

socio-economic and product-related factors [30]. Like Suanmali's empirical framework, our study examines how socio-demographic characteristics, environmental perceptions, and health-related factors shape individuals' valuation behaviour. The parallels in research objectives—understanding determinants of WTP for public or quasi-public goods—justify the application of logistic regression in the present study. This methodological precedent enhances the robustness of our approach and aligns with established analytical practices in WTP literature.

The relationship between the explanatory variables and the probability of observing ($WTP_i = 1$) is expressed in logistic regression through the log-odds transformation:

$$\ln\left(\frac{P(WTP_i = 1)}{1 - P(WTP_i = 1)}\right) = \beta_0 + \sum_{k=1}^k \beta_k X_{ik} + \varepsilon_i$$

where ($WTP_i = 1$) represents the predicted probability that respondent i is willing to pay. X_{ik} denotes the k -th explanatory variable, and β_k is the corresponding parameter estimate. A positive coefficient indicates a higher likelihood of expressing WTP, and negative coefficients indicate reduced likelihood.

Given the multidimensional nature of WTP, the analytical framework incorporated a comprehensive set of explanatory variables reflecting socio-demographic characteristics, environmental perceptions, health conditions, and residential attributes. Specifically, the model included age group, education level, occupation type, income category, gender, perceived air pollution, household respiratory illness, and residential proximity to major roads (NearRoad) all of which are theoretically grounded determinants of environmental valuation behaviour.

The final model specification is presented as:

$$\text{logit}(WTP_i) = \beta_0 + \beta_1 \text{Age}_i + \beta_2 \text{Education}_i + \beta_3 \text{Occupation}_i + \beta_4 \text{Income}_i + \beta_5 \text{Gender}_i + \beta_6 \text{PerceivedPollution}_i + \beta_7 \text{RespiratoryIllness}_i + \beta_8 \text{NearRoad}_i + \varepsilon_i$$

Where,

- β_1 (Age): Effect of the respondent's age on their likelihood of being willing to pay (WTP).
- β_2 (Education): Influence of educational attainment on WTP.
- β_3 (Occupation): Impact of occupational status on WTP.
- β_4 (Income): Effect of income level on WTP.
- β_5 (Gender): Influence of gender on WTP.
- β_6 (Perceived Pollution): Effect of perceived pollution levels on WTP.
- β_7 (Respiratory Illness): Influence of respiratory health conditions on WTP.

- β_8 (Near Road): Effect of residing near a major road on WTP.
- ε_i : Random error term capturing unobserved influences.

Categorical predictors were included in the study through dummy coding that allows comparison across groups. Education and income categories were important, since they influence environmental preferences through awareness levels and financial constraints. Similarly, perceived air pollution and residential proximity to high-traffic roads capture exposure-based environmental risk, and household respiratory illness serves as a proxy for health vulnerability, both expected to influence positively the probability of WTP. Age, gender, and occupation represent socio-demographic controls frequently included in valuation studies to account for heterogeneity in preferences and ability to contribute.

Model estimation was conducted using maximum likelihood procedures in SPSS. Odds ratios (OR) and their corresponding 95% confidence intervals were reported to facilitate interpretation of effect sizes. Multicollinearity was assessed using variance inflation factors (VIF), and model adequacy was evaluated to ensure the robustness of the estimated coefficients through the Hosmer–Lemeshow goodness-of-fit test and pseudo- R^2 measures (Nagelkerke R^2). All statistical tests were performed at a 5% significance level.

This analytical framework provides a rigorous basis for identifying the socio-economic and environmental determinants of WTP within Khulna City. It offers empirical insights for designing targeted and equitable air pollution mitigation strategies in urban Bangladesh.

Result

Summary Statistics

Table 2 shows descriptive statistics of the entire sample for all socio-demographic, environmental, and health-related variables analysed ($N = 385$). The distribution of the dependent variable (DV) reveals that 41.82% of respondents reported WTP for better air quality, whereas the remaining 58.18% did not. This indicates a moderate level of support for air quality improvement activities among the population residing in the Khulna City area.

There is a notable statistic related to age. According to this sample, about 42.86% of the respondents are young, and 33.51% are middle-aged, with the remaining 23.64% classified as older adults (see Table 1). Significant differences were recorded across education levels: 36.62% completed high school, 30.91% had higher than high school education, and only 8.83% reported being illiterate (Table 2). This distribution corresponds to the demographic profile observed in urban Bangladesh and provides sufficient variation for understanding how education shapes environmental preferences.

Table 2. Descriptive Statistics for Respondent Characteristics and Key Study Variables

Variable	Category	Count	Percent (%)
WTP	Yes	161	41.82
	No	224	58.18
Age	Young	165	42.86
	Middle-aged	129	33.51
	Old	91	23.64
Education	Illiterate	34	8.83
	Primary	91	23.64
	High School	141	36.62
	Above High School	119	30.91
Occupation	Informal	127	32.99
	Student	63	16.36
	Government	60	15.58
	Corporate	60	15.58
	Business	75	19.48
Income Category	Low	175	45.45
	Medium	133	34.55
	High	77	20.00
Gender	Male	200	51.95
	Female	185	48.05
Perceived Air Pollution	Yes	183	47.53
	No	202	52.47
Respiratory Illness (HH)	Yes	143	37.14
	No	242	62.86
Near Road Residence	Yes	180	46.75
	No	205	53.25

Occupational categories show a diverse composition. The largest proportion is engaged in informal employment (32.99%), followed by those engaged in business (19.48%), students (16.36%), government employees (15.58%), and corporate workers (15.58%). This variability reflects the socio-economic variation in Khulna and allows for a strong evaluation of occupation-specific factors related to WTP. In terms of income, 45.45% are low-income respondents, 34.55% are middle-income, and 20.00% come from the high-income group. Sex is almost equally divided, with 51.95% males and 48.05% females in Table 2, which suggests that no gender bias exists in the sampling process.

Environmental perception ratings indicate that 47.53% of respondents consider air pollution to be a problem, but 52.47% do not perceive air quality as poor. There are health-related vulnerabilities among households: 37.14% of the sampled households (HHs) had at least one person suffering from respiratory illness. Finally, 46.75% of the participants live near major roads, and therefore a considerable proportion of this population is exposed to petrol and diesel emissions.

Knowledge of Air Pollution Impacts

Table 3 summarizes the respondents' knowledge about major health and environmental effects of air pollution. Overall, the results suggest that respondents are fairly well informed about acute respiratory outcomes, but much less so regarding serious or long-term effects. In particular, as shown in Table 3, 78.2% of the respondents identified respiratory diseases, including asthma and breathing problems, as consequences of air pollution. This level of understanding confirms previous research, which reports a strong relationship between exposure to air pollution and an increase in respiratory morbidity among children and elderly people living in urban areas [31].

A moderate level of awareness is also observed with regard to adverse health effects of air pollution on the respiratory systems of children (66.0%), which accords with previous findings of moderate respiratory impacts among school children exposed to polluted urban air [32]. Yet, awareness of more serious health risks was significantly less common among respondents. Only 52.9% acknowledged cardiovascular effects, although research identified cardiovascular disease as a significant long-term burden associated with chronic exposure to air pollution in Bangladeshi cities [33,34].

Table 3. Respondents' Knowledge of the Consequences of Air Pollution

Air Pollution Consequence	Knows/Agrees (%)	Does Not Know (%)
Causes respiratory diseases (asthma, cough, breathing difficulties)	78.2	21.8
Increases risk of cardiovascular disease (heart attack, stroke)	52.7	47.3
Leads to premature death	49.4	50.6
Affects pregnant women (preterm birth, low birth weight)	41.8	58.2
Harms children's health (pneumonia, reduced lung function)	66.0	34.0
Reduces productivity and ability to work	57.9	42.1
Damages crops, plants, and the environment	61.3	38.7
Reduces overall quality of life in the city	72.5	27.5

Knowledge regarding pregnancy outcomes and perinatal health was even lower. Only 41.8% recognized that low birth weight or preterm delivery are potential risks of pregnancy. Yet years of epidemiological evidence show a strong association between exposure to particulate matter and adverse pregnancy outcomes [35,36]; risks of PM-induced foetal abnormalities, infant respiratory mortality, and low birth weight are higher in polluted urban conditions. The relatively poor level of knowledge among respondents implies a wide knowledge gap concerning the effects of air pollution on maternal and child health. Although district-specific clinical data for Khulna are

limited, studies from Bangladesh have demonstrated that exposure to ambient air pollution is associated with low birth weight, preterm birth, and increased neonatal morbidity, particularly in densely populated urban settings. This suggests that similar risks exist in Khulna. It is important to improve awareness among respondents.

Effects on the environment were better understood. Most respondents (61.3%) knew that air pollution kills crops and vegetation, as reported in a national study where it was highlighted that environmental degradation is one of the most widely recognized outcomes of pollution [34]. Similarly, 72.5% of participants stated that air pollution lowers the quality of life in the city overall, reflecting broader global research suggesting that economic and social strains associated with poor air quality are pressing issues internationally. As Khulna represents a specific urban setting with unique socio-environmental and exposure conditions, aggregated Bangladesh-level data may not fully capture its realities.

These findings imply that although respondents are well informed regarding acute respiratory impacts, knowledge of chronic and severe health effects—such as cardiovascular hazards and pregnancy-related outcomes is limited. This pattern is consistent with findings from other regional and global studies, emphasizing the necessity for public education campaigns.

Self-Reported Health Effects of Air Pollution

Table 4 shows the proportion of respondents experiencing self-reported health-related exposure to air pollution among residents of Khulna. The findings suggest a significant burden of pollution-related health outcomes in the study population. Almost half of the respondents (49.1%) reported having experienced chronic cough or throat discomfort, suggesting that respiratory distress is among the most frequent and immediate adverse outcomes resulting from exposure to dirty air. This agrees with previous epidemiological evidence indicating that fine particulate matter (PM2.5), vehicular pollution, and dust are common causes of upper respiratory irritation among urban residents.

Table 4. Health Symptoms Experienced by Respondents

Health Symptom	Yes (Count)	Yes (%)	No (Count)	No (%)
Cough/persistent throat irritation	189	49.1%	196	50.9%
Shortness of breath	142	36.9%	243	63.1%
Eye irritation/watery eyes	167	43.4%	218	56.6%
Headaches/dizziness	129	33.5%	256	66.5%
Chest tightness/discomfort	98	25.5%	287	74.5%
Allergy-like reactions (sneezing, runny nose)	153	39.7%	232	60.3%

Eye symptoms were also very common, including redness, burning sensations, and weeping (43.4%). These ocular responses are well accepted as short-term sentinel effects of poor air quality in crowded urban areas. Sneezing and runny nose—both allergy-mimicking symptoms—were also reported by 39.7%, indicating that this group is more susceptible to particulate matter and airborne pollutants.

Dyspnoea, a more alarming respiratory symptom, was present in 36.9% of respondents. Evidence of impaired lung function is an indication of more substantial respiratory disease and likely reflects conditions such as asthma or low lung function that are known to be exacerbated by fine particulate pollutants. One third of respondents (33.5%) reported headaches and dizziness, in line with a body of work associating air pollution with lower oxygen supply and increased physical stress. Other symptoms and signs, such as chest tightness, which is less commonly experienced (25.5%), may still be an important factor indicating possible cardiopulmonary strain and should be taken into account.

Factors Influencing Willingness to Pay for Improved Air Quality

Table 5 presents the results of the binary logistic regression model identifying the key factors shaping respondents' willingness to pay (WTP) for improved air quality in Khulna City. Similar to previous environmental valuation studies [11,17,22], the model incorporates a mix of socio-demographic, environmental, and health-related variables—namely age, education, occupation, income, gender, perceived air pollution, respiratory illness, and residential proximity to major roads. These variables were selected based on established literature and contextual expert insights. They are recognized determinants of urban household valuation for environmental improvements in developing countries.

Perceived air pollution emerged as a strong and significant predictor of WTP ($CE = 0.8046$, $p < 0.01$). The marginal effect indicated that respondents who perceived air pollution as a problem were 16.67% more likely to express WTP than those who did not, as shown in Table 5. Two previous studies reported that heightened pollution awareness increases the likelihood of supporting environmental improvement measures [17,22].

Table 5. Binary Logistic Regression Estimates of Factors Influencing Residents' WTP for Improved Air Quality

Variable	Coef (β)	Odds Ratio	95% CI	p-value
Age (ref: Middle)				
Young	0.3473	1.415	0.796 – 2.515	0.2365
Old	0.4682	1.597	0.797 – 3.200	0.1866
Education (ref: Above High School)				
High School	-1.0133	0.363	0.206 – 0.639	0.0004***
Primary	-0.8783	0.415	0.211 – 0.820	0.0113**
Illiterate	-1.0280	0.358	0.129 – 0.989	0.0474*
Gender (ref: Female)				
Male	-0.2922	0.747	0.479 – 1.164	0.1975
Income (ref: High)				
Medium	0.1401	1.150	0.614 – 2.157	0.6622
Low	-0.2589	0.772	0.418 – 1.425	0.4081
Occupation (ref: Business)				
Informal	0.9333	2.543	1.328 – 4.868	0.0049**
Corporate	0.6196	1.858	0.847 – 4.075	0.1221
Government	0.2680	1.307	0.599 – 2.853	0.5008
Student	0.2102	1.234	0.554 – 2.746	0.6067
Residential Exposure (ref: Not Near Road)				
Near Road	0.4835	1.622	1.034 – 2.543	0.0351*
Perception & Health (ref: No)				
Perceived Pollution	0.8046	2.236	1.394 – 3.587	0.0008***
Respiratory Illness	0.6009	1.824	1.174 – 2.833	0.0075**
Hosmer–Lemeshow χ^2	21.49 (p = 0.0059)			
ROC–AUC	0.72			
Nagelkerke R ²	0.207			

Odds ratios were computed as $\exp(\beta)$ to facilitate interpretation of effect sizes. Health vulnerability also played a substantial role. Households reporting respiratory illness showed a significantly higher probability of WTP (CE = 0.6009, ME = 0.1361, $p < 0.01$) in Table 5. This finding agrees with previous research which found that individuals experiencing pollution-induced health burdens demonstrate greater WTP for air quality interventions [22,37]. This supports the premise that direct health impacts intensify perceived benefits of pollution mitigation. Residential exposure, measured through proximity to major roads, also significantly influenced WTP. Respondents living near busy roads were 10.01% more willing to pay (CE = 0.4835, $p < 0.05$), reflecting increased exposure to vehicular emissions. Similar exposure-related WTP patterns were reported proximity to pollution sources heightened health concerns and WTP [17].

Education showed a clear negative relationship relative to the highest education category. Individuals with high school (CE = -1.0133, $p < 0.01$), primary (CE = -0.8783, $p < 0.05$), and no formal education (CE = -1.0280, $p < 0.05$) were significantly less willing to pay compared to those with education above high school. This pattern is consistent with studies which observed that higher

educational attainment enhances environmental awareness and understanding of pollution risks, also increasing WTP[11,17,38].

Occupation also demonstrated a significant effect. Respondents engaged in informal employment were 19.33% more likely to express WTP (CE = 0.9333, $p < 0.01$), possibly indicating greater exposure to outdoor environments and pollution-related health risks. Although this factor was not directly examined by all comparison studies, higher exposure among informal workers is consistent with broader urban environmental health literature.

In contrast, income and gender were not statistically significant in this model, despite multiple studies identifying strong positive effects [11,38]. This may be attributable to the relatively narrow distribution of income levels in the sample or to the dominance of health- and exposure-related factors in predicting WTP.

Perceived pollution increases the odds of expressing willingness to contribute by approximately $\exp(0.8046)$ in terms of effect magnitude. This indicates a substantial behavioural response to environmental risk perception. Similarly, households reporting respiratory illness exhibit significantly higher odds of WTP. Direct health experience affects environmental valuation.

Conversely, lower educational attainment significantly reduces the odds of WTP relative to respondents with education above high school.

Model Diagnostics and Goodness of Fit

The Hosmer–Lemeshow goodness-of-fit test was statistically significant ($\chi^2 = 21.49$, $p = 0.0059$). This suggests some deviation between observed and predicted probabilities. Although this may indicate calibration limitations, the test is known to be sensitive in moderately sized samples and categorical predictor structures. Since the model gives acceptable discriminatory performance (ROC–AUC = 0.72) and stable coefficient estimates across nested specifications, the regression results remain suitable for explanatory interpretation rather than predictive forecasting.

Multicollinearity diagnostics were assessed prior to model estimation. All predictor variables exhibited variance inflation factor (VIF) values below the conventional threshold of 5, indicating no serious multicollinearity concerns.

Overall model performance and coefficient stability suggest that the estimated relationships are statistically reliable for interpretative and policy-oriented analysis.

Interaction Effects and Model Refinement

To examine whether socio-economic characteristics moderate the relationship between environmental perception, health vulnerability, and WTP, interaction terms were introduced into the logistic regression model. Specifically, interactions between education and perceived pollution, as well as between income category and respiratory illness, were tested.

The interaction model demonstrated comparable discriminatory power (ROC–AUC = 0.72) and improved explanatory capacity (Nagelkerke R^2 = 0.207). The interaction terms were not statistically significant at conventional levels, suggesting that the primary effects of perception and health vulnerability remain robust across socio-economic subgroups.

These findings indicate that environmental risk perception and direct health experience influence WTP consistently, irrespective of educational attainment or income category. Thus, the main-effects model remains theoretically and empirically stable.

Robustness Analysis

A sequence of nested logistic regression models was estimated to assess the robustness of the estimated relationships. Model 1 included socio-demographic characteristics only (age, education, occupation, income, and gender). Model 2 introduced environmental exposure variables, specifically perceived pollution and residential proximity to major roads. Model 3 further incorporated household respiratory illness as a health vulnerability indicator. Model 4 represents the full specification.

Table 6 presents comparative results across model specifications. The inclusion of environmental exposure variables substantially improved model fit, increasing Nagelkerke R^2 from 0.091 (Model 1) to 0.173 (Model 2) and reducing the Akaike Information Criterion (AIC). The addition of household respiratory illness further enhanced explanatory power (R^2 = 0.195) and improved model discrimination (ROC–AUC = 0.72).

Coefficient signs and statistical significance levels remained stable across specifications, indicating internal consistency and robustness of the primary findings. These results confirm that exposure-based and health-related factors significantly strengthen predictive performance beyond socio-demographic controls, reinforcing the central role of perceived risk and vulnerability in shaping environmental financial commitment.

Table 6. Robustness Model Comparison of Nested Logistic Models

Model	Variables Included	Nagelkerke R ²	AIC	ROC–AUC
Model 1	Socio-demographic only	0.091	522.38	0.649
Model 2	+ Environmental Exposure	0.173	500.54	0.709
Model 3	+ Health Variable	0.195	494.99	0.720
Model 4	Full Specification	0.195	494.99	0.720

Note: Model 1 includes socio-demographic variables (age, education, occupation, income, and gender). Model 2 adds environmental exposure indicators (perceived pollution and residential proximity to major roads). Model 3 further incorporates household respiratory illness. Model 4 represents the full specification. AIC = Akaike Information Criterion. ROC–AUC = Area Under the Receiver Operating Characteristic Curve.

Discussion

The findings of this study emphasize the role of perception and personal health experience in shaping residents' economic valuation of air quality improvements in Khulna City. In line with behavioural and environmental economics literature, subjective risk perception appeared to be a critical determinant of WTP for pollution mitigation. Evidence from Hanoi indicates that individuals who perceive air pollution as severe demonstrate stronger financial commitment to environmental improvement initiatives [6]. Likewise, our results suggest that perceived pollution significantly influences stated WTP behaviour. Yet, only 47.53% of respondents in Khulna considered air pollution to be a serious local crisis. This figure may partially explain lower aggregate WTP levels relative to more heavily polluted metropolitan areas in Bangladesh, as previously documented by Ashikuzzaman *et al.*[8].

Direct health experience was also a statistically significant predictor of valuation behaviour. Empirical evidence from pollution-prone urban areas in Bangladesh indicates that residents reporting respiratory symptoms or pollution-related health problems exhibit stronger concern and higher WTP for mitigation measures [15]. Our findings are similar, as respondents experiencing frequent breathing difficulties or respiratory illness demonstrated a 13.61% higher likelihood of expressing WTP towards air quality improvement. The broader literature suggests that lived exposure and household-level vulnerability increase the salience of environmental risks, thereby strengthening the economic valuation of environmental quality.

The research also points to significant gaps in understanding long-term systemic health effects of air pollution. Knowledge of respiratory effects seems relatively high; awareness of cardiovascular risks, maternal health implications, and chronic disease pathways remain low. Previous studies [39] also reported that knowledge of general air pollution among Bangladeshi residents is adequate, but detailed understanding of long-term cardiovascular and reproductive health effects is inadequate.

These asymmetries may limit WTP at higher levels, leading to underestimation of the long-term benefits associated with pollution reduction, owing to incomplete risk perception.

These results have important policy implications. Firstly, risk communication approaches should focus on long-term cardiovascular and maternal health risks in order to garner public support for air quality policies. Secondly, improving air quality monitoring, especially in roadside corridors and industrial areas, could build greater public trust, which might be converted into WTP. Thirdly, urban planning which includes health concerns is likely to be gratefully welcomed by the general public. This will lead to a higher level of WTP.

A significant and not entirely expected result is the lack of relevance of income to WTP. Income is usually positively related to environmental valuation in wealthier settings and the non-significance of this variable in our study could mean that income variation within our sample was relatively small or that health-related vulnerability may be exerting more influence on behaviour. This indicates that in secondary cities with relatively high levels of pollution, experiential exposure and perceived risk might be more important than pure financial capacity in regard to WTP. Thus, policy should focus on vulnerability, not income levels.

The broader environmental governance implications of the findings relate to the fact that valuation behaviour in secondary cities such as Khulna is influenced not only by income constraints, but also by perception dynamics, health vulnerability, and local contextual factors. Local empirical evidence should lead to equitable air quality financing mechanisms.

Limitations

This study relies on a cross-sectional design and convenience sampling, which limit causal inference and generalizability. Future research employing longitudinal designs and probability-based sampling would enable stronger identification of temporal changes in WTP and provide more robust evidence on causal pathways between perception, health vulnerability, and environmental valuation. Incorporating objective pollution exposure measurements alongside subjective perception indicators would further strengthen analytical precision.

Conclusion

This study provides focused, empirical evidence from Khulna City that residents' willingness to pay for air-quality improvements is affected by perceived pollution, direct health experience, exposure, occupational context and education. Respondents who perceived local air pollution as problematic were roughly 17 percentage points more likely to express WTP, and households reporting respiratory illness were about 14 percentage points more likely, effects that mirror findings from other urban studies in the region. Living near major roads and working in informal,

outdoor occupations further increased WTP. Conversely, lower educational attainment markedly reduced the likelihood of WTP.

This study estimates determinants of expressed financial willingness rather than monetary valuation amounts. Because the survey employed a binary WTP measure without eliciting specific contribution levels, the findings should be interpreted as behavioural indicators of support for air-quality improvement rather than aggregate welfare estimates. Future research incorporating payment scales or bid amounts would allow more precise estimation of economic value.

Acknowledgments

The authors express their sincere gratitude to all respondents from Khulna City who generously contributed their time and information to this study.

Ethics Approval

This study was conducted in accordance with established ethical principles for research involving human participants and adhered to the provisions of the Declaration of Helsinki, as fully stated in section 4.8.

Data Availability

The data sets generated and analysed during the current study are available from the corresponding author upon reasonable request.

Code Availability

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

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