Impact of Air Pollution on Prices of Real Estate and the Internal Structure of Bahraini Metropolitan Area

Salem R. Buhammoud[1], Ahmed O. El-Kholei[1*] and Omar Al Ubaydli[2]

[1]Department of Natural Resources and Environment,
Arabian Gulf University, Manama, Kingdom of Bahrain
[2]Bahrain Center for Strategic, International and Energy Studies,
Awali, Kingdom of Bahrain

*E-mail: aelkholei@agu.edu.bh

Received: 22/09/2021
Revised: 27/10/2021
Accepted: 15/11/2021

Abstract

In 2017, the World Bank estimated the cost of air pollution in Bahrain at 0.1 percent of the Gross National Income (GNI) using health statistics that the World Health Organization (WHO) publishes. Anthropogenic activities in an area cause environmental pollution. Using Gross Domestic Product (GDP) to estimate the cost of air pollution appears to be more accurate. In Bahrain, between 2009-2019, respiratory diseases were not among the top four causes of death. The paper quantifies the cost of air pollution in Bahrain's urban areas using real estate prices. The researchers adopted the willingness-to-pay approach to investigate the connection between air quality, the spatial distribution of population, and real estate price using Geographic Information Systems (GIS) and advanced multivariate statistical techniques. The usage of GDP is adequate and trustworthy compared to GNI. Air pollution accounted for 16.7% of the variation in house prices, leaving 83.3% to other confounding variables, such as transboundary sources of air pollution.

Keywords: Air quality, willingness-to-pay; hedonic prices; GIS; Advanced Multivariate Statistical techniques.

Introduction

Air pollution is one of the utmost urban environmental problems. Every year, about seven million people die because of air pollution around the world. Approximately 90% of those residing in cities[1] breathe air containing air pollutants that exceed WHO guideline limits (WHO, 2017). Anthropogenic activities[2] degrade air quality in urban areas.

Air pollution has its economic costs in various forms, including increased morbidity and mortality rates and damage to assets, such as cultural monuments. The combined effects of ambient (outdoor) and household air pollution result in approximately seven million premature deaths, primarily due to increased mortality from stroke, lung cancer, chronic obstructive pulmonary disease, heart disease, and acute respiratory infections (WHO, 2017, 2021). For example, in 2013, the World Bank and the Institute for Health Metrics and Evaluation (IHME) concluded that the world's economy lost about US$225,000 million in labor

[1] Statistics show that most of them are in cities of developing countries.
[2] Including manufacturing, traffic congestion, thermal power generation plants, and Sewerage Treatment Plants (STPs).

income, which is equivalent to approximately the GDP of India, Canada, and Mexico combined (Narain et al., 2016).

One indirect means for estimating the cost of air pollution is using effects on health by determining the gravity of air pollution and the degree to which it affects people.[3] The Global Burden of Disease assesses how personal exposure affects people's risk of becoming sick. Narain et al. (2016) valued the economic costs of premature mortality because of emissions in dollar terms using two distinct approaches:

1. According to households' willingness-to-pay (WTP), a welfare-based method monetizes air pollution's increased fatality risk. Besides, the welfare-based approach quantifies the economic costs of fatal health threats to individuals because air pollution threatens many amenities people enjoy, including consumption, leisure, wellness, and being alive.
2. An income-based method measures the monetary cost of premature death to the current value of lost lifetime earnings. Thus, the income-based approach is adequate for financial analysis and estimating costs of emissions within the national accounts.

Each approach adapts to various objectives. Narain et al. (2016), however, gave each method an equal weight in their analysis.

In 2017, World Development Indicators (WDI) showed that Bahrain's per capita GNI was US$19,840 and that 88.8 percent of the total population resided in urban areas. WDI also showed that the per capita energy use was 10,395 kg oil equivalent. The per capita electric power consumption was 19,225 kWh; 100.0 percent of the electricity generated was from fossil fuel, and the per capita CO2 emissions reached 23.7 metric tons (World Bank, 2017).

The Global Health Metrics (2020) and the IHME (2020) showed that between 2009-2019, the top causes of death were ischemic heart disease. Diabetes came second, and the third was strokes, while lung cancer and lower respiratory infection ranked sixth and eleventh, respectively. Smoking and burning incense in closed air-conditioned spaces are traditional practices. Both are degrading indoor air quality and are among the causes of lung cancer and lower respiratory infection. Using health statistics does not seem to be a suitable measure to assess the cost of air pollution in Bahrain.

The World Bank calculated the cost of air pollution in Bahrain at 0.1 percent of the GNI. It is not clear why the World Bank used the GNI in the calculations, not the GDP, which is a statistic that breaks down a country's economic production, while the GNI is the GDP plus the country's net earnings of primary income from abroad. Pollution results from anthropogenic activities that take place in a location.[4] Thus, the use of GDP in estimating the cost of air pollution seems more realistic. Using GDP agrees with the method that Narain et al. (2016) used in their investigation.

Several scholars estimated the impact of air pollution using real estate prices. Hedonic prices reflect implicit values measuring the median consumer's appreciation of local public goods, such as air quality (Kahn, 2017). Saptutyningsih (2013) used housing property prices to value the air quality indirectly in Yogyakarta, Indonesia. Another

[3] Market prices are the measures used to value a natural resource, such as forest, fisheries and land. In the case of an environmental asset, such as air quality, researchers use indirect methods, such as impact on health or real estate.

[4] It could be country, a region, or a city.

research calculated the impact of mining sites on the value of dwellings. Papatheodorou et al. (2012) noticed that a location one kilometer away from a mining site equates to a US$6,000 increase in the property's price. Ridker and Henning (1967) argued that air quality correlates with prices of properties, then assessed the impact of air pollution on property prices.

To prepare for a post-oil era, Bahrain is on track to diversify its economy. In 2019, the share of oil in GDP was 17.8%. The growing non-oil sectors include finance, manufacturing, and tourism. The real estate sector is among Bahrain's significant economic sectors. In 2019, the real estate sector contributed about 5.4% of the non-oil GDP (Ministry of Finance and National Economy, 2020).

The paper attempts to calculate the cost of air pollution indirectly using land prices in Bahraini metropolitan areas. Assuming other things being equal, the location of a parcel of land determines its market price. There is an inverse relationship between land price measured in Bahraini Dinar (BD)[5] per sq. ft and its location measured by the distance away from a stationary source of air pollution. Therefore, a dweller will pay an extra Bahraini Dinar to avert any nuisance by residing in a location further away from a source of air pollution. The research tries to assess air pollution's impact on Bahrain's real estate sector using data from the public notary and air monitoring stations.

Material and Methods

The researchers adopted the WTP approach to inquire about the relationship between air quality and real estate prices. They used quantitative research methods, including GIS and advanced multivariate statistical techniques, to reveal common attributes and differences in land parcel location because of air pollution. They collected data from various governmental agencies, including, but not limited to, the Public Commission for Protecting Marine Resources, Environment and Wildlife; Information & eGovernment Authority; and the Supreme Council for Environment.

The researchers identified the geographical coordinates[6] for (a) the eight air monitoring stations and (b) the stationary sources for air pollution to generate air pollution patterns using an extension for kriging in ArcGIS. After reviewing the descriptive statistics to guarantee the data statistical analysis' reliability and validity, the researchers normalized the data and calculated the logarithmic value of land price to assure the linearity of the dependent variable. The researchers then used the mean values employed in the statistical analysis.

The researchers computed the correlation coefficients to test the associations between the different variables, and the results showed a significant association between several variables. The researchers conducted Principal Component Analysis (PCA) to avoid multicollinearity between the variables in the multiple regression analysis. Next, they performed a Varimax rotation to maximize the sum of the squared loadings' variances and saved the PCA scores to generate thematic maps and conduct discriminant and multiple regression analyses to estimate the cost of air pollution.

[5] One Bahraini dinar is 2.65 United States dollars.
[6] They monitor the following 12 air pollutants: NH3, NO2, H2S, SO2, CO, O3, PM10, PM2.5, Benzene, Toluene, Xylene, and Total Nonmethane hydrocarbons (TNMHC).

Results

1. Geography

Bahrain is a 36-island archipelago in the Arabian Gulf. The two most populous islands are Bahrain and Muharraq. Bahrain comprises four governorates: Capital, Muharraq, Northern, and Southern. Between 2011 and 2015, the area of the islands grew from 767.3 to 778.4 m2 (Information & eGovernment Authority, 2017). Land reclamation[7] is a way to make more land available for an increasing population, a thriving economy, and a protective measure against climate change-related sea-level rise.

2. Population

The Bahraini population is young. In 2016, the population of Bahrain reached 1.424 million, of which 665 thousand were Bahrainis, the remaining were ex-pats. The dependency ratio was 57.1. Bahraini males were 337 thousand, while male ex-pats were 552 thousand (Information & eGovernment Authority, 2017). According to Naumann et al. (2018), a UNICEF report issued in 2013 showed that India, Bangladesh, Pakistan, Egypt, and the Philippines are the top five nationalities of workers in Bahrain. Naumann et al. (2018) cited a report that the Embassy of India in Bahrain issued in 2018 claiming that nearly 300 thousand Indians lived and worked in Bahrain, thus making them the country's largest expatriate group. Although Egyptians come fourth among the top five nationalities of workers in Bahrain, in 2010, their remittances per migrant worker toped other four nationalities reaching $18,826, while the remittances per Indian worker were only $2,998 (Naumann et al., 2018).

In 2017, Bahrain's score on the Human Development Index was 0.846. In 2016, the adult literacy rate (% ages 15 years old and over) reached 95 percent, and the adult mortality rate, male and female, was 1.1 and 0.8 per 1000 people, respectively. Meanwhile, the labor force reached 71.2 percent of those ages 15 years old and over (Naumann et al., 2018).

3. Weather

The weather in Bahrain is a scorching desert. The winter runs from November to April temperature is moderate, about 20.8°C, fluctuating rainfall from year to year, an annual average of 74 mm and a high temperature of 32°C. The summer runs from May to October, which is usually hot. Bahrain's weather is highly humid throughout the year, with an average annual humidity of about 81% and a minimum of 45% (Szczepanski, 2016; Index Mundi, 2017). Precipitation is between November to April, and Bahrain experiences the maximum precipitation usually during January. Wind usually blows from the northwestern direction.

The average temperature in Bahrain appears to have increased from 1995 to 2011. Meanwhile, the rainfall has changed, coinciding with an increase in the number of days of dust and low visibility, having adverse effects on vision, eye, nose, and chest.

4. Sources of air pollution

There are four groups of stationary sources of air pollution. WTPs and both Askar and Al-Hafeera landfills[8] represent the first group. Bahrain has 12 WTPs that treat about

[7] The process of forming new land from lakes, rivers, riverbeds, or lake beds is known as land fill.
[8] Askar landfill receives domestic solid wastes, while Al-Hafeera landfill recieves hazardous wastes.

224,710 m3 per day. According to the Ministry of Public Works, Municipalities, and Urban Planning, the daily flow is 352,772 m3. The plan is to expand existing WTPs and develop new facilities to meet growing needs, which will increase the emission of air pollutants. WTPs and landfills are sources of methane, ammonia, VOCs, and hydrogen sulfide.

Oil extraction and manufacturing plants make up the second stationary source of air pollutants, such as sulfur oxides and nitrogen oxides. In 2019, the share of oil and manufacturing sectors in the GDP was 17.80 and 14.50 percent. They are among the exporting economic sectors. Power generation and water desalination plants make up the third stationary source of air pollution. In 2013, these plants produced about 35.60 percent of the water supply (Al Ansari, 2013) using fossil fuels to generate electricity and desalinate water. Both manufacturing establishments and plants for power generation and desalination are the sources of Volatile Organic Compounds (VOCs)[9] and NOx compounds[10] that react with sunlight and produce SMOG,[11] negatively affecting human health and can cause premature death.

The fourth stationary source of air pollution is airports. They emit Greenhouse Gases (GHG)[12] and generate solid wastes. Airports are sources of noise. They attract and generate trips, thus causing traffic congestions. Lowering GHG emissions, and potentially reducing noise, is possible by improving fuel usage.

In 2006, total GHG emissions were 29,153 GgCO2e, with 20,149 Gg coming from energy, 8,704 Gg from industrial processes and product use, and 268 Gg from waste. CO2e emissions from agriculture and other land use were about 33 Gg, which declined to 8 Gg for these carbon sinks. In 2006, net national emissions were 29,128 Gg (Aljenaid et al., 2020).

5. Land prices

Real estate development is a significant contributor to Bahrain's economy. In 2017, the sector experienced its highest growth rate in years, and a new government program to increase the supply of affordable housing boosted the construction sector. Besides, Bahrain's commercial real estate has boomed because of growing demand from the leisure and tourism sectors. The authorities have recently introduced several regulatory reforms, including establishing the Real Estate Regulatory Authority securing long-term growth by assuring accountability and transparency in the real estate market (Oxford Business Group, 2021).

Construction costs raised slightly. In July 2017, Bahrain required private developers to pay BD12 ($31.80) per sq meter to extend infrastructure and services to new urban developments. The strategy supported the real estate sector as no one can expect to get infrastructures for free. The government charges Bahrainis lower municipal fees and lower tariffs for drinking water and electricity compared to those that ex-pats pay. The result is offering Bahrainis affordable housing, as the Oxford Group reported in 2021.

The government demarcated specific locations known as free-holding, where foreigners

[9] Gases released into the atmosphere as a result of using fossil fuel. Once in the air, they can react with other gases, resulting in the formation of other air pollutants. VOCs include benzene, ethylene glycol, formaldehyde, methylene chloride, tetrachloroethylene, toluene, xylene. They can be carcinogenic.

[10] Nitric oxide and nitrogen dioxide.

[11] Fog and Smoke episodes.

[12] These are gases resulting from human activities and contribute to climate change. They include carbon dioxide; methane; nitrous oxide and fluorinated gases.

can buy land and dwellings. These areas include some of the best-inhabited zones in Bahrain, such as Amwaj island in Muharraq; Abraj al Lulu, al Juffair, and al Reef Island in Capital Governorate; and Durrat al Bahrain and Durrat Marina established in the Southern Governorate. Many of these free-holding areas result from land reclamation.

The price contour lines map (Figure 1) shows around 15 price peaks; most of them are in areas where the government applied the free-holding policy. The steep slope in the price contour line refers to raising the price by at least two units. The researchers developed imaginary buffer lines 250m around each source of pollution, and they show the relationship between the stationary source of air pollution and each price peak. It is worth mentioning that all the price peaks are on the pollution buffer zones' outer lines. Notice that prices are steeper on the north side of Manama seaside, i.e., Diplomat and Seef development areas.

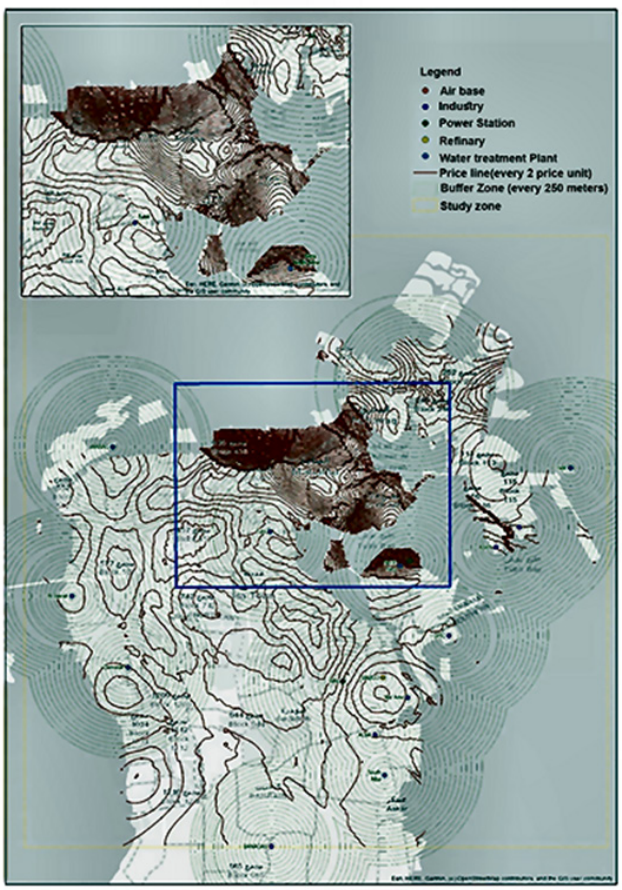


Figure 1. Land Prices, 2019

The analysis includes 347 blocks distributed among the four governorates of Bahrain. The researchers used 14 variables. Table 1 exhibits their descriptive statistics. Variables include the price of a parcel of land BD/sq. ft., which is the dependent variable. Distance from the stationary source of air pollution and concentration of air pollutants are the independent variables. Demographic variables, such as the population stratified by nationality (Bahraini and Non-Bahraini), are independent variables.

Table 1. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Price (BD/Ft^2)	347	0.000	120.000	28.213	16.660
Distance to the nearest source of pollution (m)	347	321.551	17,504.663	3224.577	1,575.351
NH_3 (ppb)	347	0.009	12.801	4.470	3.290
NO_2 (ppb)	347	0.331	35.911	13.191	9.257
H_2S (ppb)	347	0.493	10.093	3.865	2.776
SO_2 (ppb)	347	7.479	17.746	11.031	2.647
CO (ppm)	347	0.407	0.600	0.477	0.052
O_3 (ppb)	347	42.278	47.194	44.214	1.332
PM10 (mg/m^3)	347	125.518	194.324	165.852	17.254
PM2.5 (mg/ m^3)	347	0.000	47.891	43.992	3.618
Benzene (ppb)	347	0.002	0.235	0.125	0.066
Toluene (ppb)	347	0.003	0.416	0.221	0.117
Xylene (ppb)	347	0.002	0.277	0.148	0.077
TNMHC (ppm)	347	0.003	0.402	0.214	0.112
Bahraini	347	0.000	10,318.000	1,773.790	1,815.203
Non-Bahraini	347	1.000	30,852.000	1,963.310	3,104.798
Valid N (listwise)	347				

6. Analyses

The researchers calculated the Pearson correlation coefficients to examine the relationship between the price of a parcel of land and different air pollutants. The relationship is significant but not substantial, as the coefficient shows. The correlation coefficient of price with NO2, H2S, CO, O3 reached 0.210, 0.221, 0.259, and 0.270, respectively, significant at the 0.01 level (2-tailed). The correlation matrix reveals strong associations between the different air pollutants.

6.1. Principal Component Analysis

The researchers performed PCA as an exploratory statistical procedure to (a) reduce the number of variables used in the analysis, (b) internalize any possibility of multicollinearity in estimating the regression function, and (c) produce a map summarizing the data. The test resulted in three PCs explaining almost 85 percent of the variation in the study area, Table 2.

Table 2

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.911	61.944	61.944	9.911	61.944	61.944
2	2.223	13.896	75.840	2.223	13.896	75.840
3	1.404	8.776	84.616	1.404	8.776	84.616

Extraction Method: Principal Component Analysis.

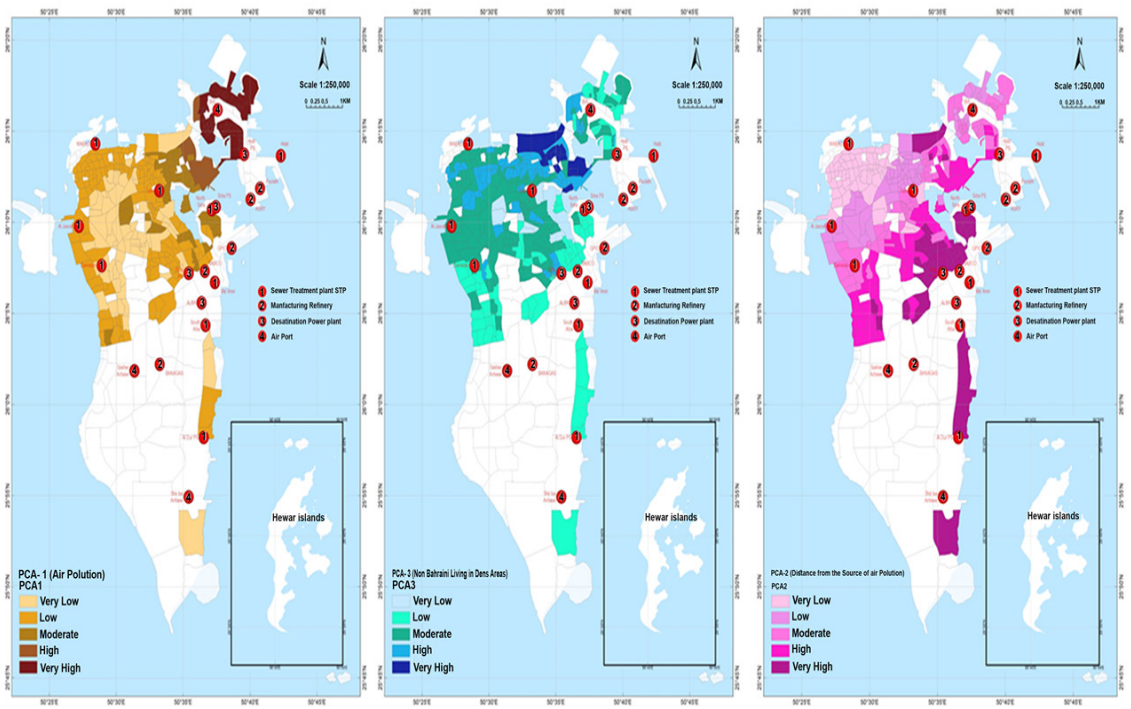
The component matrix (Table 3) suggests that the first PC loaded with NO2, H2S, SO2, CO, and O3, with loads that reached 0.910, 0.966, 0.589, 0.919, and 0.945, respectively, Figure 2, thus the component reflects air quality. PC2 associates positively with being Non-Bahraini and located to the nearest stationary air pollution source, where the loads reached 0.409 and 0.388. PC2 has an inverse relationship with NH3 and SO2, where the loads approached -0.66 and -0.75 (Figure 2). Density and Non-Bahraini are the two significant contributors to PC3 with loads that reached 0.626 and 0.778, the component reflects attributes of the population and their distribution spatially, Figure 2.

Table 3. Component matrix

[a]Variable	Component		
	1	2	3
NH_3 (ppb)	0.706	-0.662	0.214
NO_2 (ppb)	0.910	0.277	-0.197
H_2S (ppb)	0.966	0.166	-0.119
SO_2 (ppb)	0.589	-0.749	0.254
CO (ppm)	0.919	0.311	-0.189
O_3 (ppb)	0.945	0.252	-0.143
PM10 (mg/ m^3)	-0.867	0.471	-0.135
PM2.5 (mg/ m^3)	0.348	0.216	-0.060
Benzene (ppb)	-0.994	0.062	0.026
Toluene (ppb)	-0.994	0.062	0.026
Xylene (ppb)	-0.994	0.053	0.025
TNMHC (ppm)	-0.994	0.053	0.025
Density	0.296	0.595	0.626
Bahraini	0.295	-0.074	0.323
Non-Bahraini	0.259	0.409	0.778
Nearest source of Pollution	0.707	0.388	-0.244

Extraction Method: Principal Component Analysis

a. 3 components extracted.



a) PC 1: Air quality **b) PC 2: Areas with less ammonia and SOx** **c) PC 3: Non-Bahraini living in dense areas**

Figure 2. Blocks stratified according to principal components scores

6.2. Discriminant analysis

The researchers examined the distribution of the variables within Bahrain using discriminant analysis, an exploratory and explanatory statistical test. The analysis yielded three discriminant functions. The first explains 94.3% of the variation in the study area, Table 4. Wilks' Lambda[13] is extremely low for the first function, confirming its importance to classify Bahrain's blocks among the four governorates. Table 6 shows Wilks' Lambda affirming the significance of the three discriminant functions.

Table 4

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	9.106[a]	94.3	94.3	0.949
2	0.441[a]	4.6	98.8	0.553
3	0.114[a]	1.2	100.0	0.320

a. First three canonical discriminant functions used in the analysis.

Table 5

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-Square	df	Sig
1 through 3	0.062	953.050	12	0.000
2 through 3	0.623	161.946	6	0.000
3 through 3	0.898	36.96	2	0.000

[13] The likelihood-ratio test and multivariate analysis of variance both employ Wilk's Lambda probability distribution in multivariate hypothesis testing.

The mathematical specification of the three discriminant functions are:

Equation 1
$$DF\ 1 = -0.279\ \log_{10} Price + 1.303\ PC1 - 0.095\ PC2 + 0.37\ PC3$$

Equation 2
$$DF\ 2 = -0.279\ \log_{10} Price + 0.124\ PC1 + 0.886\ PC2 + 0.222\ PC3$$

Equation 3
$$DF\ 3 = 0.771\ \log_{10} Price - 0.138\ PC1 - 0.212\ PC2 + 0.371\ PC3$$

Variables that measure air quality loaded the first discriminant function (Equation 1), as the structure matrix (Table 6) shows. The function explains 94.3% of the variation in the study area, Table 4. The second discriminant function (Equation 2) reflects the distance from the source of air pollution (Table 6), explaining 4.6% of the variation in Bahrain, as Table 4 shows. The third discriminant function (Equation 3), which is loaded by the price of land, explains the remaining 1.2% of the variation.

Table 6

Structure matrix

Variable	Function		
	1	2	3
Air pollution	0.685*	0.601	-0.267
Distance from the stationary source of air pollution	-0.130	0.896*	-0.425
Log_{10} Price	0.071	0.242	0.863*
Non-Bahraini living in dense areas	0.031	0.232	0.559*

Notes:

1. Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions.
2. Variables are ordered by the absolute size of correlation within the function.
   * Largest absolute correlation between each variable and any discriminant function

Table 7 shows that the researchers classified 70.6% of the blocks of Bahrain adequately. In Manama (110 blocks), only 51 blocks share similar attributes representing 46.4% of Manama's blocks. Other blocks of Manama share similar characteristics with the Northern (30%) and Southern governorates (23%). Muharraq stands alone, yet three blocks from Manama share similar attributes with Muharraq.

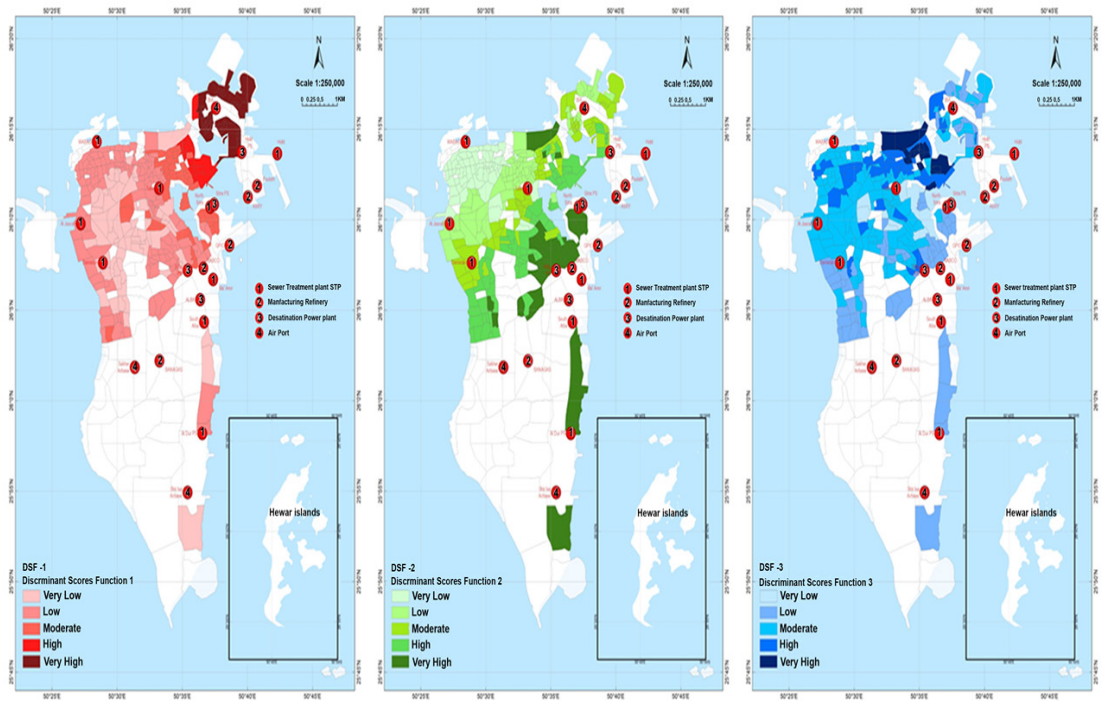
Table 7

Classification results

		Predicted Group Membership Governorates				Total
	Governorates	Manama	Muharraq	Northern	Southern	
Count	Manama	51	3	33	23	110
	Muharraq	0	53	0	0	53
	Northern	0	0	94	31	125
	Southern	0	0	12	47	59
%	Manama	46.0	3.0	30.0	21.0	100.0
	Muharraq	0.0	100.0	0.0	0.0	100.0
	Northern	0.0	0.0	75.0	25.0	100.0
	Southern	0.0	0.0	20.0	80.0	100.0

Note: 70.6% of original grouped cases are classified correctly.

Most stationary sources of air pollution are on the main island, such as the Riffa power station and Tubli STP. The boundary between governorates is a thin line passing along a major route. The administrative boundaries of the governorates, coupled with the government's free-holding policy, which associates with land reclamation in the northern area of Manama and Muharraq, could explain this result. Figure 3 depicts blocks stratified according to their discriminant scores.



a) Air quality

b) Distance from the stationary source of air pollution

c) Log_{10} Price and Non-Bahraini living in dense areas

Figure 3. Blocks stratified according to discriminant scores.

6.3. Regression

Equation 4 depicts the regression equation. Using the PCA scores and nature of air polluters as a dummy variable,[14] the regression model resulted in an R2 of 0.167, i.e., these variables explain only 16.7% of the variation in land prices (log10 Price), Table 8. The result is not suitable for prediction but could be suitable to estimate the cost of air pollution.

Table 8

Model summary

R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
				R Square Change	F Change	df1	df2	Sig. F Change	
0.408	0.167	0.157	0.23907	0.167	17.089	4	342	0.000	1.042

[14] In regression analysis a dummy variable is one that only accepts the values 0 or 1 to indicate the presence or absence of a dummy independent variable.

Equation 4

$$\log_{10} Y = 1.494 + 0.120\,PC\,1 - 0.037\,PC\,2 + 0.075\,PC3 - 0.06\,T$$

where Y is the price; PC 1 is air quality; PC 2 is the distance from the source; and PC 3 is a non-Bahraini living in dense areas. T is a dummy variable showing the stationary source of air pollution where (1) is STP and landfill, (2) is manufacturing and refinery, (3) is power and desalination plants, and (4) is airports.

Table 9 shows the beta weights[15] of the independent variables, suggesting that averting sources of air pollution and dense areas where most non-Bahrainis live are the most determining variable. Air quality is among other variables determining a household's choice when deciding to rent or buy a dwelling.

Table 9

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		Collinearity Statistics		
	B	Std. Error	Beta	Sig	Tolerance		VIF
(Constant)	1.494	0.038		39.296	0.000		
Air pollutants	0.120	0.024	0.460	5.039	0.000	0.292	3.424
Distance from the stationary source	-0.037	0.013	-0.144	-2.913	0.004	1.000	1.000
Non-Bahraini residing in dense areas	0.075	0.013	0.288	5.765	0.000	0.974	1.027
Type of air polluter source	-0.060	0.020	-0.271	-2.954	0.003	0.290	3.451

7. Cost of air pollution

Based on the R2, air pollution, which results from stationary sources, explains only 16.7% of the variation in land prices. Knowing that the real estate sector represents 5.7% of the Bahraini economy, then the cost of air pollution is US$3,500 million (Table 10).

Table 10

Cost of air pollution, 2019

Item	Value
Bahrain GDP 2019 (USD)	$385,738,570,000.000
Non-Oil GDP (%)	82.200%
Share of Real Estate Sector GDP (%)	5.700%
Share of Real Estate Sector in Non-oil GDP (%)	4.440%
Cost of air pollution (USD)	$3,671,845,447.830
Cost of air pollution as percent of GDP, 2019 (%)	0.952%
Population of Bahrain	1,641,000.000
Per capita share of the cost of air pollution, 2019 (USD)	$2,237.566
Per capita share of the cost of air pollution, 2019 (BD)	3933.540

[15] A normalized regression coefficient is referred as a beta weight (the slope of a line in a regression equation). When both the criterion and predictor variables are standardized, they are employed (i.e. converted to z-scores). When there is only one predictor variable, a beta weight equals the correlation coefficient.

Discussion

The researchers' estimate is close to the World Bank and conceptually more realistic because GDP is the basis, not the GNI. Air quality explained about 16.7% of the variation of prices in the real estate market, leaving 83.3% to other confounding variables, such as traffic congestion, the free-holding policy, and transboundary sources of air pollution that the research did not address.

The research supports the use of WTP and hedonic prices as an indirect approach for estimating environmental degradation. The results and findings are in line with theories of environmental economics. Bahraini officials can use these findings to elaborate on environmental policies and land use plans to attain SDG 11.

The research did not address other factors that degrade air quality. Bahrain is a populous and small island country; thus, land allocated for roads is limited, explaining traffic congestion. Vehicles are a significant source of air pollution, which is a parameter that the research did not address. Because the Arabian Peninsula is desert, Bahrain is subject to dust storms that increase levels of the suspended particular matter. If there were an inventory list of air pollutants by the source that includes data on mobile sources and transboundary sources of air pollution, the coefficient of determinations, i.e., the R2, would have been higher. Lacking this data limits the appropriate assessment of the impact of air pollution on real estate prices. A WTP assessment needs a qualitative analysis through interviews and surveys to augment the quantitative analysis. Because of the outbreak of COVID 19, it was not possible to conduct face-to-face interviews.

The policies of the Kingdom provided Bahrainis with affordable, decent housing. However, these policies led to an imperfectly competitive market, which affected the results of the research. The analysis, however, illustrated the effects of air pollution on real estate prices.

The results confirm the concept of social area analysis that Shevky and Bell (1955) elaborated. It reveals three main aspects characterizing an urban settlement: (a) socioeconomic variations, such as population stratified by income; (b) socio-demographic differences and (c) sociocultural differences, where the population is classified by race, ethnicity, or religion (Ostendorf and Musterd, 2012).

The results reveal the different social areas that make up the Bahraini metropolitan areas. They reflect the contradictions of a modern metropolis, where the poor Non-Bahrainis, most of them are Indians and Bangladeshis who earn less than BD 299 each month (Naumann et al., 2018), live in expensive areas, such as downtown Manama. The affluent ex-pats live in expensive areas, such as al Juffair, Amwaj Islands, and al Seef away from the sources of air pollution. Population density of downtown blocks internalizes the high rent for a parcel of land, while the better off ex-pats can afford expensive locations. After discovering oil, most Bahrainis left Manama for new urban areas, such as Isa Town and Hamad Town, and the low-income workers filtered in these dwellings in Manama, where approximately nine persons live in a room (El-Kholei, Aljenaid and Kadhem, 2019). The poorly ventilated and crowded rooms are among the reasons for the outbreak of the COVID-19 virus among the poor ex-pat community. On 19 May 2020, the Bahraini Ministry of Health registered 190 new active cases, of which 117 are expatriate workers (@MOH_Bahrain, 2020).

The results show that the Kingdom of Bahrain successfully located stationary sources of

air pollution, such as Bahrain Petroleum Company and Aluminum Bahrain, downwind on the eastern side of the main island, thus disbursing emissions away from the inhabited areas. However, the Kingdom is subject to transboundary emissions from stationary sources of air pollution in the Arabian Peninsula.

Conclusions and Implications

Using health statistics might assess the impact of air pollution in a comparative study. Because of the specificity of many countries, such as Bahrain, this method might not be suitable. Using WTP and hedonic prices might be the adequate approach to conduct the analysis. Besides, assessing the cost of air pollution using GNI is not appropriate. Using GDP is appropriate and more reliable, particularly in nations with investments abroad, such as Arabian Gulf countries. The WTP to avert environmental nuances or gain an environmental amenity seems more reliable in estimating the costs of air pollution.

Using the case of the Kingdom of Bahrain, the researchers showed the usefulness of employing hedonic prices and WTP as a conceptual framework for analysis. Using a mix of GIS applications and advanced multivariate statistical techniques generated results that show the various social areas that comprise the metropolitan area of Bahrain. The results confirm theories for the city's internal structure that Shevky and Bell (1955) elaborated. The research explained the contradictions of the modern metropolis, where the poor live in the expensive areas of the city—an argument that Wingo (2016), Kain (1962), Muth (1969), Mills & Ferranti (1971), and Wheaton (1977b, 1977a) provided empirical proof based on the fundamentals of urban geography, location theory and space economy.

The findings show that the Kingdom of Bahrain effectively located stationary sources of air pollution downwind on the main island's eastern side, dispersing emissions away from populated areas. Bahrain's policies have provided Bahrainis with reasonably priced and formally developed homes served with state-of-the-art infrastructures.

Air pollution accounted for 16.7% of the variance in real estate values, leaving 83.3% to other confounding variables like the mobile sources of air pollution and transboundary sources of air pollution, which the researchers did not address. A model of structured equations could be on the agenda for future research. Also, conducting a qualitative analysis could improve the findings of the paper. The researchers' estimate is comparable to that of the World Bank and theoretically more realistic because GDP, not GNI, is the foundation. To achieve SDG 11, Bahraini officials might use these findings to develop environmental regulations and land use plans.

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تأثير تلوث الهواء على أسعار العقارات والبنية الداخلية لمنطقة الحضرية البحرينية

سالم راشد بوحمود[1]، أحمد عثمان الخولى[1]* وعمر أحمد العبيدلى[2]

[1] قسم الموارد الطبيعية والبيئة، جامعة الخليج العربي، مملكة البحرين

[2] مركز البحرين للدراسات الاستراتيجية والدولية ودراسات الطاقة، العوالي، مملكة البحرين

*بريد الكتروني : aelkholei@agu.edu.bh

المُستَخلَص

تاريخ استلام البحث: 2021/09/22
تاريخ تعديل البحث: 2021/10/27
تاريخ قبول البحث: 2021/11/15

في عام 2017، قدر البنك الدولي تكلفة تلوث الهواء في البحرين بنسبة 0.1 ٪ من إجمالي الدخل الوطني واستخدام الإحصاءات الصحية التي تنشرها منظمة الصحة العالمية، تلوث البيئية هو نتاج الأنشطة البشرية من انتاج واستهلاك في منطقة محددة، يبدو أن استخدام الناتج المحلي الإجمالي لتقدير تكلفة تلوث الهواء أكثر دقة. في حالة مملكة البحرين حيث توضح بيانات الصحة أن بين عامي 2009-2019، لم تكن أمراض الجهاز التنفسي من بين الأسباب الأربعة الرئيسية للوفاة، لذلك تقدر الورقة تكلفة تلوث الهواء في المناطق الحضرية في البحرين باستخدام أسعار العقارات، حيث تبنى الباحثون نهج الاستعداد للتمويل للتحقيق الصلة بين نوعية الهواء من جانب، والتوزيع المكاني للسكان وأسعار العقارات باستخدام نظم المعلومات الجغرافية (GIS) والتقنيات الإحصائية المتقدمة المتعددة المتغيرات من جانب أخر. أظهرت النتائج أن استخدام الناتج المحلي الإجمالي كاف وجدير بالثقة مقارنة باستخدام الدخل القومي الإجمالي لتقدير التكلفة الاقتصادية لتلوث الهواء. أوضحت النتائج أن تلوث الهواء يشكل 16.7% من التباين في أسعار العقارات، مما ترك 83.3% لمتغيرات أخرى مثيرة للالتباس، مثل مصادر تلوث الهواء العابرة للحدود تستحق ادماجها في التحليل لتقدير أكثر واقعية لتكلفة تلوث الهواء.

مفاتيح الكلمات: نوعية الهواء، الرغبة في السداد، الأسعار الهيدونية؛ نظام المعلومات الجغرافية، تحليلات إحصائية متقدمة متعددة المتغيرات.