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Unveiling Citizens' Perceptions, Attitudes, and Behaviors towards Air Quality: Insights from a Survey in the Po Basin Area

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Abstract

Air pollution has far-reaching environmental and social consequences, requiring the active participation of individual citizens in improving air quality by means of emission-reducing behaviors. This research examines the relationship between citizens' knowledge, perceptions of air quality, attitudes towards policy measures, and intentions to adopt environmentally-friendly behaviors to combat air pollution. A comprehensive survey is conducted among a representative sample from seven regions in the Po basin area: Emilia-Romagna, Friuli-Venezia Giulia, Lombardy, Piedmont, Province of Trento, Valle d'Aosta, and Veneto. The survey aims at profiling participants based on their level of information, perceptions of air pollution, and attitudes towards emission-reducing behaviors. Cluster analysis identifies meaningful differences among citizen groups in terms of their awareness and intentions to engage in specific behaviors. Four distinct clusters emerge, each characterized by varying levels of willingness to embrace pro-environmental behaviors and support air quality improvement initiatives. By examining these profiles, the study uncovers patterns in citizens' awareness, concerns, and acceptance of environmentally-friendly practices. The findings offer valuable insights for policymakers to develop targeted interventions, policies, and communication strategies.

Keywords

Air Quality, Air Pollution, Cluster Analysis, Sustainable Development

1. Introduction

Air pollution is a pressing global concern with far-reaching environmental and

social implications. As of today, a considerable portion of the European population and ecosystems are still exposed to air pollution levels that exceed European standards, and notably, the more stringent Air Quality Guidelines (AQGs) set by the World Health Organization (WHO) [1]. Recognizing the significance of air quality as a major concern, the European Union (EU) has been actively addressing this issue. Air pollution is indeed at the center of the European Green Deal's Zero Pollution Action Plan, which was adopted in 2021. Besides setting ambitious targets to minimize harmful emissions in key sectors (such as transport, industry, agriculture, and energy production), this comprehensive plan emphasizes the need to adopt sustainable lifestyles and consumption patterns to reduce air emissions effectively, stressing the need for engaging citizens in the EU and empowering individuals to take an active role in combating air pollution and improving air quality [2].

Engaging citizens in the fight against air pollution entails raising awareness about the impacts of air pollution on human health and ecosystems, as well as promoting behavioral changes that contribute to reduced emissions [3]. In turn, in order to promote a shift towards more environmentally-friendly behavior, it is essential to gain insights into the general public's level of knowledge and perception regarding the issue. This includes understanding individuals' attitudes and preferences towards existing mitigation measures and behaviors. Surveys conducted by the European Commission reveal that public perception of air quality has indeed shifted over the past decade: around 56% of Europeans believe that air quality has deteriorated in the last ten years, while 16% perceive an improvement. Concerns are primarily directed towards emissions from cars and trucks (96%) as well as industrial production and fossil fuel power stations (92%), which are often cited as the major contributors to air pollution [4]. Despite such insights, there is still a lack of comprehensive knowledge regarding European citizens' awareness of air quality issues, their perceptions of air pollution, and their attitudes and intentions towards adopting behaviors aimed at mitigating air pollution.

In this framework, the EU-funded PREPAIR project aims to play a pivotal role in promoting sustainable lifestyles and consumption patterns among citizens in one of the most affected areas in Europe, the Po river basin in northern Italy. The presence of industrial activities, extensive transportation networks, and high population density, combined with geographical factors such as the Po Valley's topography and climate patterns, contributes to the region's high air pollution levels, also exacerbating risks for public health [5]. To address this issue, the project encompasses awareness-raising and dissemination activities that aim to educate and engage the public, private entities, and local communities.

One of the key objectives of the project is to investigate the interaction between citizens' level of information and perceptions of air quality, as well as attitudes towards policy measures and intention to adopt environmentally-friendly behaviors for mitigating air pollution. In fact, air quality perceptions have been

found to depend on individual psychology, social factors, and environmental conditions like pollution exposure [6] [7] [8]. Sociodemographics such as age, education, gender, and health also matter [9] [10] [11].

An extensive survey was conducted among a representative sample of citizens of seven regions located in the Po basin area (*i.e.* Emilia-Romagna, Friuli-Venezia Giulia, Lombardy, Piedmont, Province of Trento, Valle d'Aosta and Veneto) with the objective of profiling individuals in terms of level of information about air quality, perceptions of air pollution and attitudes toward the adoption of behavior aimed at mitigating emissions. Accordingly, cluster analysis was employed to identify significant differences among groups of citizens regarding their perceptions of issue salience and behavioral intentions.

The contribution of the study is threefold: first, the research deepens the understanding of the interaction between perceptual variables and behavioral intention in the context of air pollution mitigation. Second, by profiling citizens in terms of air quality perceptions, level of information and behavioral intentions, the research provides valuable insights for policy makers at EU, national and local levels. These insights can inform the development of information strategies that promote public engagement in combating air pollution and encourage the widespread adoption of environmentally-friendly behaviors. Third, the information emerging from the study can also be useful for companies to gain awareness of consumer attitudes toward air pollution and develop consistent mitigation actions.

2. Background and Research Objective

Air pollution is a significant threat to public health and the environment [12]. Research has highlighted the detrimental effects of poor air quality on respiratory and cardiovascular health: particulate matter (PM2.5), nitrogen oxides (NOx), and tropospheric ozone (O_3) are associated with cancer, respiratory and cardiovascular diseases, and premature mortality [13]. Recent studies suggest that air pollution may play a role in the transmission of respiratory viruses, such as COVID-19: airborne particles and pollutants can act as carriers, prolonging the life of viral particles and promoting their spread over longer distances [14]. Emissions of particulate matter and aerosols also interact with climate change, as they can absorb sunlight and contribute to localized warming, particularly in areas with high carbon emissions like urban and industrial areas [15]. Changes in weather patterns, such as increased temperatures and altered precipitation, can impact the dispersion and transport of air pollutants, intensifying their effects on human health and the environment [16]. In addition, air pollution imposes substantial economic costs on the EU, amounting to billions of Euros annually [12].

In the last decade, increasing concerns over air quality led policy makers—at EU, national and local levels—to adopt increasingly stringent policies and deploy measures to mitigate air pollution, encompassing a wide range of economic

sectors [16]. Achieving meaningful progress indeed requires a holistic approach that combines technological advancements with structural reforms, and behavioral transformations. In this latter regard, European citizens have been increasingly emphasized as main actors in the fight against air pollution: through daily choices and behaviors, citizens indeed play a significant role as drivers of change towards more environmentally—sustainable production and consumption patterns [17].

Through the adoption of eco-conscious behaviors encompassing, for instance, the use of sustainable mobility options (such as public transportation, cycling, or walking as alternatives to driving), conscientious energy consumption practices, and responsible waste management, individuals hold the capacity to diminish their carbon emissions and actively contribute to air quality improvement within their local areas. Beyond individual efforts, citizens possess the potential to act as advocates for policy changes and lend support to initiatives that promote clean air. By voicing their concerns, actively participating in public consultations, and engaging with local, national, and international policymakers, citizens can influence the development and implementation of effective air quality policies and regulations [17].

Efforts to engage the public in combating air pollution has prompted academics to investigate factors that may foster a more proactive stance on air quality issues. In this vein, studies have examined the link between individuals' exposure to air pollution and their intentions to take action, revealing inconclusive associations between exposure and behavioral intention, often attributed to limited knowledge, information and understanding of risks [6] [8] [17]. Scholars indeed argued that the complexity of environmental issues prompt individuals to rely on "cognitive shortcuts" such as perceptions and attitudes to form judgments about issues they possess little knowledge about [18]. Accordingly, research has increasingly focused on public perceptions of air pollution in order to understand the formation of heuristics that influence eco-conscious behaviors and sustainable lifestyle choices [19].

Perceptions of air pollution have been found to be influenced by three primary factors: individual psychological characteristics, social characteristics, and environmental conditions, including pollution exposure [6] [7] [8]. Similar studies have identified sociodemographic factors, including age, gender, education, and health status, as correlates of air quality perceptions [10] [11]. For instance, Guo *et al.* [20] found that respondents aged over 40, with a college-level education, residing in urban residential areas were more likely to perceive air quality as poor. Furthermore, several studies have indicated that women are more likely than men to recognize the adverse health effects of air pollution or perceive air quality as poor [9] [21] [22]. Some studies have observed associations between public perceptions of air quality and pollution exposure [6] [8] [17], while others have found no such associations [7].

However, despite the existing insights, there is still limited understanding of

the interactions among individuals' perceptions of air pollution, level of information about air quality, attitudes towards air pollution policies, and intention to adopt eco-conscious behaviors. This knowledge gap particularly pertains to how these factors collectively shape diverse profiles of individuals with varying levels of proactivity towards air pollution issues [23] [24] [25]. Therefore, the present study aims to bridge this gap by examining how citizen clusters based on variables such as perceptions of air pollution, level of information, attitudes towards policy measures and behavioral intention. The objective of such analysis is to outline key factors that determine differences among groups of citizens and that may inform the development of targeted awareness-raising and information strategies that may stimulate proactivity in less involved groups. The findings will provide valuable insights for the development of targeted awareness-raising and information strategies, which can effectively stimulate proactivity among less engaged groups. By understanding the factors that influence different levels of involvement, policymakers can design interventions that specifically address the needs and motivations of these groups, ultimately promoting greater engagement and action in combating air pollution.

3. Methods

3.1. Data Collection

Data were collected by means of a self-administered online questionnaire based on close-ended questions, draft in close collaboration with experts of air pollution. The questionnaire included five sections. The first section of the questionnaire consisted of questions regarding perceptions of air quality variation in the last decade, the most suitable approach to address the challenges posed by air quality, and the most effective initiatives to tackle air quality problems in the respondent's living area. This was followed by a series of questions aimed at gathering information on the perception of air quality in the autumn/winter and spring/summer seasons, as well as the most relevant causes of air pollution. A third section of the questionnaire focused on the willingness to adopt mitigation behaviors and attitudes towards initiatives to combat air pollution. The fourth section of questions assessed respondents' level of knowledge and information regarding air quality and air pollution, as well as the use of different sources to access information on air quality. The last questions aimed to collect essential socio-demographic, including the location of the residence in relation to the municipality and geographically.

Data collection took place between December 2022 and January 2023. In order to reach a wide and representative audience of respondents, thereby making the collected information even more significant, a "social" multichannel methodology was adopted for administering the questionnaire. This allowed respondents to complete the questionnaire via the web, accessing it through Facebook, Instagram, and other social networks. In the final period of the data collection, we pursued strategies to close the quotas set by the sampling design, carried out

through promotional actions on social networks aimed at improving coverage in relation to the sampling objectives.

3.2. Sample Description

The survey targeted the adult population living in the Po Valley region, specifically in Piedmont, Lombardy, Emilia-Romagna, Veneto, Friuli-Venezia Giulia, Valle d'Aosta, and the Province of Trento. To ensure a representative sample, the sampling plan follows a stratification approach based on three variables: 1) territorial area (region/province), 2) age group (20 - 39, 40 - 65, 65+), and 3) gender (male, female). The overall goal was to collect 5000 questionnaires, distributed across the different regions as indicated in Table 1.

At the end of the data collection, a total of 7030 questionnaires were received. Among these, 7004 questionnaires were attributed to 1623 different municipalities in the area, while 26 questionnaires lacked information about the municipality. It is worth noting that the targeted area comprises a total of 4280 municipalities with a population of 25.9 million residents. Therefore, the coverage achieved was 38% in terms of the total number of municipalities in the area and 78% in relation to the resident population. By examining the distribution of municipalities by size ranges, as shown in Table 2, no significant territorial concentrations were observed. The survey encompassed all 42 provincial capitals in the area, where a total of 6.7 million inhabitants resides, accounting for approximately 33% of the overall population in the region. Within these provincial capitals, 2574 questionnaires were collected, constituting 37% of the total number of questionnaires received. Due to the large number of responses collected and the lack of territorial concentrations, a high level of representativeness was ensured both in terms of geographical distribution and personal characteristics of the respondents, including age, gender, and education level. The distribution of the universe and the sample according to geographical and personal data is presented in Table 3.

Table 1. Sampling targets by region and resident population (as of January 2022).

Region	Population	%	Proportional sample	Actual sample
Emilia-Romagna	3,743,110	17.5%	875	850
Friuli Venezia Giulia	1,024,056	4.8%	239	380
Lombardy	8,346,281	39.0%	1.951	1.600
Piedmont	3,631,332	17.0%	849	800
Province of Trento	449,629	2.1%	105	350
Valle d'Aosta	104,466	0.5%	24	120
Veneto	4,093,170	19.1%	957	900
Total	**21,392,044**	**100%**	**5000**	**5000**

Table 2. Representativeness of the sample in terms of size of municipalities.

Size of the municipality (no. of inhabitants)	Population		Sample	
	No. of municipalities	%	No. of municipalities	%
Up to 4999	3102	72.5%	709	43.6%
5000 - 14,999	880	20.6%	637	39.2%
15,000 - 49,999	253	5.9%	236	14.5%
50,000 - 299,999	42	1.0%	41	2.5%
Over 300,000	3	0.1%	3	0.2%
Total	**4.280**	**100%**	**1.626**	**100%**

Table 3. Territorial/demographic characteristics of the population and sample of respondents.

		Population[1]		Sample	
		n.	%	n.	%
Region	Piedmont	3,616,582	18%	804	11%
	Valle d'Aosta	103,649	1%	130	2%
	Lombardy	7,891,298	38%	3266	46%
	Province of Trento	417,487	2%	352	5%
	Veneto	3,943,410	19%	1051	15%
	Friuli Venezia Giulia	1,015,839	5%	381	5%
	Emilia-Romagna	3,583,759	17%	1046	15%
	Total	**20,572,024**	**100%**	**7030**	**100%**
Size of the municipality (No. of inhabitants)	Up to 4.999	5,307,048	21%	1626	23%
	5000 - 14.999	7,153,743	28%	1706	24%
	15.000 - 49.999	5,768,257	23%	1385	20%
	50.000 - 299.999	4,423,160	18%	1513	22%
	Over 300.000	2,485,827	10%	774	11%
	Missing	-	-	26	0.4%
	Total	**25,138,035**	**100%**	**7030**	**100%**
Age	20 - 39	5,980,998	29%	2219	32%
	40 - 64	9,124,834	44%	3574	51%
	>65	5,466,192	27%	1237	18%
	Total	**20,572,024**	**100%**	**7030**	**100%**
Gender	Female	10,743,188	52%	3220	46%
	Male	9,828,836	48%	3789	54%
	Missing	-	-	21	0%
	Total	**20,572,024**	**100%**	**7030**	**100%**

[1]Data at regional level refer to the adult population, aged over 20 years. At municipality level, data refer to the total population, as data regarding adult population is not available.

Continued

Education	Lower secondary school	10,854,349	53%	493	7%
	High school diploma	7,073,321	34%	3134	45%
	University degree	2,644,354	13%	3403	48%
	Total	**20,572,024**	**100%**	**7030**	**100%**

3.3. Measurements

The following measures were utilized in the cluster analysis:

1) *Perceptions of air quality variation*—respondents were asked to rate their perceptions about air quality variation in the last decade on 3-point Likert scale, where 1 = "*it has improved*", 2 = "*it remained unchanged*" and 3 = "*it has worsened*". The majority of the sample (65.5%) perceives a decline in air quality, while a smaller proportion (9.9%) believes it has improved. 20% of respondents think it has remained unchanged, indicating a widespread perception of worsening air quality.

2) *Level of information about air quality*—respondents were asked to self-asses their level of information about air quality in their town or city, on a 5-point Likert scale, where 1 = "*very well informed*" and 5 = "*not informed at all*". Around 27.1% of the sample deemed themselves knowledgeable, comprising 5.2% "*very well informed*" and 21.9% "*well informed*". Conversely, 28.9% perceived themselves as "*poorly informed*" or "*not at all informed*". The majority, representing 43.4%, fell into the category of "*partially informed*".

3) *Information sources about air quality*—respondents were asked to indicate their main source of information about air quality and pollution, picking among the following: web; social networks; television; newspapers; smartphone apps; radio; other. The web is the top information tool (29%), followed by social networks (17.07%), traditional media like television (16.87%) and newspapers (14.25%). Smartphone apps were chosen by 11.33% of respondents, while the radio was the least used (5.53%). Some respondents reported not using any of these means (3.35%), and a few mentioned using other sources (2.53%).

4) *Intention to adopt behaviors to mitigate air pollution*—respondents were asked to rate their willingness to adopt different eco-conscious behaviors to mitigate air pollution on a 5-point Likert scale, where 1 = "*Not at all*" to 5 = "*Totally willing*". The list of behaviors included the following: a) prefer public transport; b) use bicycles when possible; c) choose efficient vehicles (hybrid, electric, fuel-efficient); d) install low-emission boilers; e) limit air conditioner usage; f) reduce home heating temperature; g) upgrade to heat pumps for heating; h) use cleaner alternatives to fireplaces and wood/pellet stoves; i) improve home energy efficiency; j) buy local products to reduce emissions from transportation; k) stay informed about air quality and follow recommendations; l) engage in voluntary activities for raising awareness. Over 60% of respondents express at least some willingness to implement these good practices. Personal

commitment for volunteer activities shows the lowest level of willingness, while purchasing high-efficiency, low-emission boilers receives the highest level of willingness. Buying local products, improving home energy efficiency, and using sustainable modes of transportation also receive significant levels of willingness.

5) *Attitude towards policy measures*—respondents were asked to rate their attitude towards different policy measures aimed at mitigating air pollution, on a 5-point Likert scale where 1 = "*totally against*" to 5 = "*totally in favor*". The list of policy measures included the following: a) traffic limitations and controls in urban areas; b) restricted zones and pedestrian areas; c) ban on private heavy vehicle circulation in cities; d) promoting cycling and walking; e) lowering speed limits; f) regulations on biomass heating systems; g) enhanced boiler regulations; h) incentives for environmentally friendly agriculture. Respondents highly favor initiatives supporting agricultural practices with limited atmospheric impact and modal shift towards cycling and electric scooter sharing. Surprisingly, these initiatives were not considered as effective by a significant percentage of respondents. However, overall, respondents show favorable attitudes towards all the initiatives.

4. Results

4.1. Variables Modelling through Factor Analysis

The cluster analysis was performed on the basis of 10 distinct variables. Among these variables, 3 were questionnaire items (observed variables), while 7 variables (latent factors) were derived by means of a factorial analysis. Specifically, the 3 questionnaire items concerned: 1) perceptions of air quality variation, 2) level of information about air quality and 3) information sources about air quality. Factor analysis was instead conducted on two sets of questionnaire items concerning: a) intention to adopt behaviors to mitigate air pollution and b) attitude towards policy measures.

Factor analysis is a multivariate statistical technique used to explore relationships between observed variables and identify underlying latent factors. In essence, factor analysis reduces the dimensionality of the observed variables by grouping together those that exhibit higher similarity. The results of the factor analysis highlighted 7 distinct factors emerging from the observed variables: specifically, 5 factors emerged from the questionnaire items concerning intention to adopt behaviors to mitigate air pollution, while 2 factors emerged from items concerning respondents' attitude towards policy measures. Table 4 displays questionnaire items from both constructs alongside the newly generated variables.

4.2. Cluster Analysis

Cluster analysis is a robust statistical methodology extensively employed in academic research, particularly in disciplines such as marketing and socioeconomic studies. Its primary objective is to discern homogeneous groups of entities—in

Table 4. Variables modelling through factor analysis.

Measure	Questionnaire item	Latent factor
Intention to adopt behaviors to mitigate air pollution	Prefer public transport	Sustainable mobility
	Use bicycles when possible	
	Choose efficient vehicles (hybrid, electric, fuel-efficient)	Environmentally-conscious purchases
	Install low-emission boilers	
	Limit air conditioner usage	Regulating home temperature
	Reduce home heating temperature	
	Upgrade to heat pumps for heating	
	Use cleaner alternatives to fireplaces and wood/pellet stoves	Energy-efficient behaviors
	Improve home energy efficiency	
	Buy local products to reduce emissions from transportation	Responsible and sustainability-oriented actions
	Stay informed about air quality and follow recommendations	
	Engage in voluntary activities for raising awareness	
Attitude towards policy measures	Traffic limitations and controls in urban areas	Sustainable mobility
	Restricted zones and pedestrian areas	
	Ban on private heavy vehicle circulation in cities	
	Promoting cycling and walking	
	Lowering speed limits	
	Regulations on biomass heating systems	Domestic efficiency and agricultural sustainability
	Enhanced boiler regulations	
	Incentives for environmentally friendly agriculture	

this case, individuals—within a dataset by delineating patterns and variations based on specific criteria. By identifying clusters of similar entities, this analytical approach facilitates the exploration of underlying structures and relationships.

The cluster analysis was performed using the STATA 17 software to examine the relationship between 10 variables. As previously mentioned, out of these variables, 7 were derived through factor analysis, while the remaining 3 variables were directly derived from the questionnaire. The aim was to categorize individuals into distinct groups based on their perceptions about air quality variation, level and sources of information, attitudes towards policy measures and intentions to engage in eco-conscious behaviors.

As a result, four distinct clusters of citizens were identified, each characterized by varying degrees of willingness to adopt pro-environmental behaviors and support initiatives aimed at improving air quality. From a detailed analysis of the four clusters, significant differences emerge. Accordingly, the clusters were named according to the most salient characteristics, as follow:

Cluster 1. "*Engaged and proactive*"—This is the largest cluster comprising citizens who display a strong willingness to contribute to improving air quality. They are highly supportive of implementing initiatives to combat air pollution. Their perception of the change in air quality over the past decade is relatively less negative compared to other groups. They are also the most informed about air quality, with the web and social networks being their primary sources of information. This cluster demonstrates a significant commitment to various proposed actions, showing a greater interest in adopting virtuous behaviors across all areas. They are particularly interested in actions related to monitoring home temperature, adopting energy-efficient practices, and promoting responsible and sustainable behaviors. Unlike other clusters, they are supportive of mitigation initiatives related to sustainable mobility, domestic efficiency and agricultural sustainability.

Cluster 2. "*Willing to commit, but in the right measure*"—This cluster comprises a smaller number of citizens who only partially demonstrate a willingness to engage in improving air quality. They show interest in actions such as monitoring home temperature and adopting responsible sustainability practices. However, they exhibit medium-low availability for other behaviors like sustainable transportation, eco-friendly purchases, and energy efficiency. Regarding mitigation initiatives, they are more inclined towards sustainable mobility but less supportive of domestic efficiency and agricultural sustainability. They rate air quality variation over the past 10 years worse than the "Engaged and proactive" cluster, but less than the other two clusters. Their level of information on air quality is moderate, with newspapers and radio being their main sources.

Cluster 3. "*Win-win approach*"—This cluster consists of citizens who demonstrate little willingness to take action to improve air quality, except for behaviors that offer personal economic benefits alongside environmental benefits. They are only willing to engage in efficient and sustainable purchases, particularly hybrid, electric, or fuel-efficient vehicles, and high-efficiency, low-emission boilers, which can result in cost savings. They are not supportive of mitigation initiatives, especially those related to domestic efficiency and agricultural sustainability. They perceive a negative change in air quality over the past 10 years. Their level of information on air quality is the lowest, with mobile apps and social networks being their preferred sources, while newspapers are not considered.

Cluster 4. "*Disinterested and unavailable*"—This cluster comprises citizens with the least interest in committing to reduce air pollution. While the perception of air quality variation is not significantly different from other groups, they tend to have a more negative perception overall. Despite perceiving a higher deterioration in air quality, they express a strong unwillingness to adopt any behaviors to reduce pollution. They also show a lack of support for mitigation initiatives.

Table 5 displays the results of the cluster analysis, providing mean values of each analysed variable, while Table 6 displays the distribution of sample respondents across the four clusters.

Table 5. Cluster analysis results: average values of the variables analyzed in each cluster.

Cluster	Variables														
			Sources of information												
	Perceptions of air quality variation	Level of information	Web	Newspapers	Smartphone app	Radio	TV	Social networks	Sustainable mobility	Environmentally-conscious purchases	Regulating home temperature	Energy-efficient behaviors	Responsible and sustainability-oriented actions	Domestic efficiency and agricultural sustainability	Sustainable mobility
Engaged and proactive	2.52	2.82	0.99	0.18	0.18	0.001	0	0.27	0.06	0.07	0.08	0.08	0.09	0.05	0.07
Willing to commit, but in the right measure	2.58	2.94	0	1	0.11	0.97	0.39	0.19	−0.03	−0.02	0.03	−0.01	0.02	0.034	0.02
Win-win approach	2.61	3.2	0.09	0	0.39	0.19	0.07	0.37	−0.03	0.017	−0.036	−0.015	−0.03	−0.0001	−0.03
Disinterested and unavailable	2.65	3.15	0.38	0	0	0.12	1	0.26	−0.07	−0.08	−0.114	−0.091	−0.083	−0.07	−0.04

Table 6. Distribution of sample respondents across the four clusters.

Cluster	No.	%
Engaged and proactive	2437	38.6%
Willing to commit, but in the right measure	1048	16.6%
Win-win approach	1631	25.8%
Disinterested and unavailable	1190	18.8%

4.2.1. Perceptions of Air Quality across Clusters

Within each cluster, respondents' perceptions of air quality—during hot and cold seasons—were assessed using two questionnaire items, corresponding to the questions: 1) "*During the autumn/winter season, how do you perceive the air quality in your neighborhood?*"; 2) "*During the spring/summer season, how do you perceive the air quality in your neighborhood?*". Participants were asked to rate their perceptions on a 5-point Likert scale, where 1 = "*Good*" and 5 = "*Harmful to human health*".

When examining the percentage distribution of responses regarding the perception of air quality among the four clusters, it becomes evident that the "Engaged and proactive" cluster demonstrates the most negative perception of air quality. This is reflected in the highest percentages of responses categorizing air quality as "*harmful to human health*" (as shown in Table 7 and Table 8). Conversely, the cluster that perceives the best air quality is the "*Uninterested and unavailable*" cluster, characterized by the highest percentages of responses

Table 7. Perceptions of air quality during hot seasons (spring and summer), relative frequency across clusters and mean.

Cluster	Good	Mediocre	Harmful to the frailest people	Harmful to human health	Don't know	Mean
Engaged and proactive	14.0%	37.9%	15.5%	31.6%	1.0%	2.30
Willing to commit, but in the right measure	17.6%	45.0%	13.8%	22.6%	1.0%	2.21
Win-win approach	18.0%	41.5%	16.0%	23.1%	1.4%	2.25
Disinterested and unavailable	19.1%	44.3%	17.3%	18.0%	1.3%	2.19

Table 8. Perceptions of air quality during cold seasons (winter and autumn), relative frequency across clusters and mean.

Cluster	*Good*	*Mediocre*	*Harmful to the frailest people*	*Harmful to human health*	*Don't know*	*Mean*
Engaged and proactive	21.7%	45.7%	14.0%	17.6%	0.9%	2.68
Willing to commit, but in the right measure	25.4%	45.5%	13.6%	13.9%	1.5%	2.44
Win-win approach	23.4%	45.7%	15.0%	14.4%	1.5%	2.48
Disinterested and unavailable	25.6%	46.9%	12.5%	13.4%	1.6%	2.38

indicating good air quality and the lowest percentages indicating air quality harmful to human health. These findings suggest a relation between the willingness to engage in actions and behaviors to mitigate air pollution and the perception of the current air quality. However, it is important and interesting to note that perceptions of current air quality and perceptions of air quality variation over the past 10 years show opposite results between some clusters. Indeed, while the "Engaged and proactive" cluster is the one that shows the worst perception of current air quality, it is also the one that perceives the least air quality deterioration in the last 10 years. The same, but with reverse considerations, applies to the "Disinterested and unavailable" group. This finding is in line with the clusters' level of information. In fact, according to data published in Legamente's report (2023), although the current level of air quality pollution in Italy is high, it has not worsened significantly over the past 10 years. Therefore, this finding shows that the most informed cluster ("Engaged and proactive") has the perceptions most consistent with objective data, while the opposite is true for the least informed cluster ("Disinterested and unavailable").

4.2.2. Perceived Causes of Air Pollution across Clusters

Lastly, we examine perceptions about sources of air pollution across the four clusters of respondents. The questionnaire indeed asked respondents to rate on a 5-point Likert scale—where 1 = "*not a cause of pollution at all*" and 5 = "*very much a cause of pollution*" – the level of responsibility for air pollution attributed to five distinct causes: 1) transportation; 2) agriculture, intensive farming; 3) industry, energy production plants; 4) heating/cooling systems; 5) wood and pellet stoves (domestic biomass).

This analysis does not reveal significant variations between the clusters. In general, all groups attribute considerable responsibility to transportation, industry, heating and cooling systems. Agriculture is perceived as least responsible cause of air pollution across the four clusters. These results are displayed in Table 9.

4.2.3. Demographic Characteristics of the Clusters

The analysis of demographic characteristics among respondents belonging to the four clusters highlights discernible distinctions, specifically in relation to age and educational attainment. The "Engaged and proactive" cluster emerges as the youngest, followed by the "Win-win approach" cluster. Conversely, the "Willing to commit, but in the right measure" cluster exhibits a higher average age.

With regard to educational qualifications, the sample comprises approximately 3000 respondents holding at least a university degree. Among them, 47% belong to the "Engaged and proactive" cluster, while 24% align with the "Win-win approach" cluster. In contrast, the "Disinterested and unavailable" and "Willing to commit, but in the right measure" clusters encompass a smaller proportion of university graduates (14% and 15% respectively). Further examination of educational profiles within the four clusters reveals that nearly 60% of the "Engaged and proactive" cluster possess at least a university degree, while only 3.6% have interrupted their education at the middle school level.

Table 9. Perceptions about causes of air pollution across clusters: mean values for each perceived cause of air pollution are reported in columns.

Cluster	Perceived causes of air pollution				
	Transportation	Agriculture, intensive farming;	Industry, energy production plants	Heating/ cooling systems	Wood and pellet stoves (domestic biomass).
Engaged and proactive	3.86	3.06	3.70	3.64	3.18
Willing to commit, but in the right measure	3.84	2.95	3.70	3.67	3.19
Win-win approach	3.77	2.95	3.64	3.56	3.14
Disinterested and unavailable	3.81	2.99	3.74	3.64	3.12

Table 10. Demographic characteristics of clusters.

Cluster	Age (%)			Gender (%)			Education (%)			Place of residence (%)			Geographic location of the home (%)			
	18 - 39	40 - 64	+65	M	F	Other	Lower secondary school	High school diploma	University degree	City center	First periphery	Countryside	Sea	Plain	Hill	Mountain
Engaged and proactive	37.83	51.21	10.96	48.67	50.96	0.37	3.16	36.89	59.95	34.1	56.59	9.31	1.57	76.83	17.02	4.58
Willing to commit, but in the right measure	17.75	49.14	33.11	47.23	52.67	0.1	7.35	49.43	43.23	33.82	57.1	9.08	2.71	75.02	17.42	4.84
Win-win approach	33.29	51.81	14.9	44.39	55.3	0.31	8.34	47.03	44.64	30.42	59.85	9.73	1.54	73.21	19.64	5.6
Disinterested and unavailable	26.39	52.52	21.09	45.21	54.54	0.25	11.26	51.93	36.81	28.86	60.1	11.04	2.45	75.21	17.26	5.08

These findings solidify the "Engaged and proactive" cluster as exhibiting the highest educational attainment compared to the other clusters. Conversely, the group characterized by the lowest educational achievement consists of citizens in the "Disinterested and not available" cluster, with the lowest proportion of graduates (37%) and the highest proportion of individuals who concluded their studies after middle school (11%). Similar trends are observed when comparing the "Willing to commit, but in the right measure" and "Win-win approach" clusters. In essence, a greater inclination to contribute to the improvement of air quality appears to correspond to a higher level of educational attainment. Lastly, no significant differences were found between the four clusters in terms of gender distribution, or their geographical location.

Demographic characteristics of the clusters are summarized in Table 10.

5. Conclusions

The objective of the research was to explore the relationship between citizens' level of information and their perceptions of air quality, as well as their attitudes towards policy measures and their intention to adopt environmentally-friendly behaviors for reducing air pollution. To achieve this goal, an extensive survey was conducted among a representative sample of citizens from seven regions in the Po basin area, namely Emilia-Romagna, Friuli-Venezia Giulia, Lombardy, Piedmont, Province of Trento, Valle d'Aosta, and Veneto. The primary aim was to profile individuals based on their level of information about air quality, their perceptions of air pollution, and their attitudes towards adopting behaviors aimed at mitigating emissions. Cluster analysis was utilized as a method to iden-

tify significant differences among groups of citizens concerning their perceptions of issue salience and their intentions to engage in specific behaviors. The analysis sought to uncover distinct patterns and profiles among the surveyed individuals, shedding light on variations in their awareness, concerns, and readiness to embrace environmentally-friendly practices.

The analysis of clusters has proven to be an effective method for profiling and categorizing respondents into distinct groups based on various social, perceptual, and behavioral variables related to air quality. These variables include the perception of air quality variation, level of information, sources of information utilized, and the adoption of behaviors aimed at mitigating air pollution. Through this analysis, four distinct clusters have emerged, each characterized by different levels of willingness to engage in virtuous behaviors and varying degrees of awareness and concern regarding air quality.

Interestingly, the distribution of these clusters within the sample is heterogeneous. Surprisingly, the cluster that displays the greatest sensitivity towards air quality, labeled as the "Engaged and proactive" cluster, is also the largest in size. This suggests that a significant portion of respondents exhibits a heightened awareness and concern regarding the state of air quality. Moreover, the clusters exhibit distinct demographic and social compositions. Specifically, the "Engaged and proactive" cluster demonstrates a higher proportion of young respondents with a greater level of education. It is within this group that the highest level of information and knowledge pertaining to air quality is observed. This finding suggests that education plays a crucial role in shaping individuals' awareness and understanding of air quality issues.

By identifying and characterizing these clusters, policymakers and stakeholders can gain valuable insights into the diverse perspectives and behaviors of different population segments. This knowledge can inform the development of targeted interventions, awareness campaigns, and policy initiatives aimed at improving air quality and promoting sustainable behaviors. In conclusion, the analysis of clusters has provided a nuanced understanding of respondents' perceptions, behaviors, and awareness levels regarding air quality. The identification of four distinct clusters, with varying levels of willingness to adopt virtuous behaviors and different demographic compositions, emphasizes the need for tailored approaches to address air pollution and engage individuals in sustainable practices.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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