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AIR QUALITY MANAGEMENT STRATEGIC FRAMEWORK FOR FUTURE SUSTAINABLE CITIES

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Abstract

Pollution can originate from fixed, mobile, and local sources, due to human activity or naturally occurring processes. The well-developed cities contribute to over 70% of global carbon emissions. This paper analyses the parameters that contribute to achieving healthy, environmentally sustainable cities. A strategic planning framework is introduced to implement efficient and effective strategies for future sustainable cities. Therefore, the paper aims to identify and examine successful factors within a framework to reduce negative environmental impacts from air pollution designed for future sustainable cities. Data is collected from locations that reflect the nature of human settlement and well-being, and Advanced SWOT analysis was conducted to see the success factors. Data analyses reveal many factors that must be monitored to achieve SDG 11 targets. The results show how air quality affects people's health and social living conditions in urbanised areas. Comparisons between pre-and-post Covid 19 indicated the impact of the pandemic on air quality and showed evidence of possible reductions in air pollution when activities are reduced. The method used for this research is analysing the data recorded from a network of environmental stations constructed at different sites in the Emirate of Ajman. The achieved framework consists of strategies categorised into five main categories, formed by different functional layers, to demonstrate actions needed by the government. Recommendations have been drawn from the findings, and if considered, it could be possible to achieve sustainable air quality. Keywords: Aerodynamics, Forebody and afterbody, Next keyword, Projectile, Supersonic speed.

Keywords: Air quality, Carbon footprint, Healthcare, SDGs, Sustainability indicators, Sustainable cities.

1. Introduction

Nearly two billion people do not have access to clean cooking facilities, and carbon emissions are expected to rise by 0.4% annually worldwide [1]. Air pollution ranks fourth among the most severe health risks in the world, following high blood pressure, dietary hazards, and smoking [2]. According to recent estimates by the WHO [3], air pollution is responsible for 6.5 million premature deaths yearly. Air pollution threatens the environment, the economy, food security, and human health. Air pollution is an issue that cannot be fixed overnight and in isolation: it is intertwined with policies concerning energy, climate, transportation, commerce, agriculture, biodiversity, and other issues [4, 5]. However, [6, 7] found that well-designed air quality initiatives offer significant co-benefits for other policy goals. Improving air quality via increasing efficiency and renewable deployment aligns with the Paris Agreement's more considerable energy sector reform and decarbonisation targets [8].

The energy sector, which encompasses the industrial, transportation, and residential sectors, is crucial in achieving the Sustainable Development Goals related to air pollution [9, 10]. The bulk of sulphur dioxide (SO2) and nitrogen oxide (NOx) emissions to the atmosphere, as well as over 85% of particulate matter (PM) emissions, are energy related. The primary sources of SO2 in the energy sector are power generation and industries. The usage of oil-based products in cars and power generation is the primary source of NOx emissions. Each of the major pollutants has a primary source and fuel. In the case of PM2.5, this refers to the wood and other solid biomass that approximately 2.7 billion people use for cooking, as well as kerosene used for lighting (and in some countries, also for cooking), which causes indoor pollution that results in approximately 3.5 million premature deaths each year [11].

The repercussions of energy poverty are largely seen in Asia and Sub-Saharan Africa's emerging countries [12]. Fine particles, whether absorbed inside or outdoors, can enter deep into the lungs, posing a serious health risk. PM2.5 exposure is not only a city concern [13]; poor air quality substantially impacts many rural populations, and a considerable portion of secondary pollutants may be transferred across long distances from their sources [14, 15]. This paper aims to demonstrate the success factors for future sustainable cities. The objective is to critically examine the strength factors of the Air Quality management strategy for the selected case study area. To demonstrate the effect of human activities on air quality by taking a case from data collected over the years 2018, 2019 and 2020. Moreover, the paper is to present an air quality framework supporting SDGs for future sustainable cities.

2. Successful Factors Supporting Healthy Air Quality

Air pollution is a significant threat to both climate change and human health, contributing to various illnesses such as respiratory and cardiovascular diseases, reproductive and nervous system dysfunctions, and cancer. Particulate matter (PM) can enter the respiratory system, causing severe health issues, while ground-level ozone negatively impacts respiratory and cardiovascular systems [16]. Other harmful pollutants include nitrogen oxides, sulphur dioxide, volatile organic compounds, dioxins, polycyclic aromatic hydrocarbons, and carbon monoxide, which can cause poisoning and disorders like COPD, asthma, lung cancer, and neurological dysfunctions.

Climate change exacerbates the spread of infectious diseases, and tackling this issue requires public awareness and coordinated efforts by scientists and institutions to develop long-term solutions [17]. Climate change caused by pollutants and natural catastrophes impacts the geographical spread of many infectious illnesses. Public awareness combined with a multidisciplinary approach by scientists is the most effective way to address this issue; national and international institutions should address the rise of this threat and suggest long-term solutions [16].

2.1. Development of sustainable cities' supporting factors

A sustainable city is one with long-term social, economic, and physical progress. It has a long-term supply of the natural resources on which its development is based (and only uses them sustainably). It also ensures long-term protection against environmental threats that might jeopardise progress. A sustainable city "must have a shape and compactness that foster social contact" [16]. These elements include low-energy settlement patterns and housing forms, a variety of land uses, public facilities, acceptable open spaces at a scale and location that reduce the need for motorised travel, and transportation strategies that prioritise walking and cycling and encourage the use of public transportation [18].

The essential advantage, however, is that compact cities promote socio-economic fairness by increasing access to services and amenities. To introduce the influential factors that are within the sustainable city framework, it is essential to consider the following facts [19]:

- Accurate data derived from the monitoring system.
- Setting objectives is implied by performance measurements (i.e. against which performance can be compared).
- Different people have different values depending on where they live.
- Factors to support sustainability in cities must be able to account for various locations, individuals, cultures, and organisations.
- Supporting factors can significantly impact how human activities impact the environment.

As cities become more complex in social, economic, and environmental aspects, sustainability is increasingly emphasized in planning and development. Decision-makers are implementing improvements to reduce resource requirements and environmental impacts. Alongside assessment methods, urban-specific indicators should be developed [20].

The TISEE framework, which includes Technology, Institutional, Social, Economic, and Environmental indicators, provides a measurable tool for monitoring sustainable city development. These indicators help support long-term economic productivity, health, and quality of life for residents. Moreover, they guide the creation of strategic documents and development programs by setting priorities and assessing the effectiveness of solutions [21]. Table 1 shows the most frequently used thematic categories within the proposed framework [21].

The construction and transportation sectors have a close relationship. In terms of energy consumption, they are regarded as the primary consumers. In the construction industry, energy consumption is divided into two categories: energy capital and energy income. Capital refers to the energy used to construct buildings and urban infrastructure.

Table 1. The most frequently used thematic categories within the proposed framework [21].

Dimensions	Thematic Categories
Technological	Accuracy and reliability of monitoring data, performance of pollution control technologies, adoption of data-driven tools by decision-makers and automated integrated system
Institutional	• Participation (civic engagement) • Urban planning (urban design or form) • Environmental Management Governance • Finance • Transparency
Social	• Education • Health • Housing (shelter) • Safety and Security • Equity (social or economic) • Social infrastructure (sanitation, social services, buildings) • Green space (public space, recreation) • Culture • Technology and Innovation • Well-being • Demography (population) • Poverty • Social inclusion
Environmental	• Water (water use, consumption, quality, management) • Mobility and transport • Waste (waste management, material consumption) • Air quality • Energy • Land use (land and nature, spatial development) • Climate change • CO_2 emissions • Noise • Biodiversity • Environment • Natural disaster • Ecological footprint • Soil
Economic	• Economy (economic development, performance, growth, strength) • Employment (unemployment, jobs, labour force) • Global appeal (economic relations, tourism) • Economic structure • Materials and products

Furthermore, energy revenue represents the energy consumed throughout a person's lifetime, as illustrated in Fig. 1.

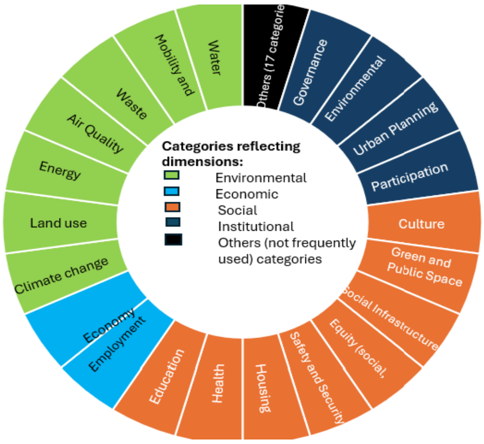

Fig. 1. The most frequently used thematic categories within the selected framework [21].

2.2. Air quality strategies and initiatives for sustainable city formation

According to the reports published by the UN, several approaches have succeeded, which indicates that we are making progress toward achieving many goals with respect to sustainable cities, particularly the issue of air quality. The United Arab Emirates, for example, is one of the most active countries in this regard. The Government has formulated a National Agenda for Sustainable Cities and implemented policies and regulations to support and guide the development of sustainable cities [22].

The UAE National Air Quality Agenda is meant to improve air quality while enabling co-benefits and synergies across various sectors, such as the Green Agenda, the National Innovation Strategy, the UAE Energy Strategy 2050, and the UAE Strategy for the Fourth Industrial Revolution. Aside from improving outdoor air, ambient odours, and noise, it also helps to enhance indoor air quality; the key strategic objectives to measure progress have been developed for each of the four areas. These objectives consider the country's maturity in each region and ensure compatibility with the Sustainable Development Goals for 2030 [23], as shown in Fig. 2.

Fig. 2. Strategic objectives for the national air quality agenda 2031 [23].

Strategic indicators have been developed to track the progress made by the agenda implementation plan, as shown in Table 2 [23].

Table 2. Strategic indicators of the national air quality agenda 2031 [23].

Strategic Objectives	Strategic Indicator	Target
Reducing outdoor air pollution levels and exposure	Percentage of compliance with the national standards	•100% compliance with national standards for gaseous pollutants by 2040 •90% compliance with the national standard of PM2.5 by 2040
	PM 2.5 concentration in residential areas	Reach 35 μg/m^3 annual average concentration of PM2.5 in residential areas by 2030
Improving indoor air quality and reducing its risks to human health quality	Number of national standards related to safeguarding indoor air quality	Increase the number of national standards issued/updated relating to safeguarding indoor air quality
Reducing levels of exposure to ambient Odors	Percentage of hourly mean concentration of hydrogen sulphide (H2S) below 10 μg/m^3 (Details not yet unavailable)	The target will be determined later as part of the agenda implementation, in consultation with stakeholders.
Reducing ambient noise levels and keeping them within permissible limits	Details not yet available The target will be determined later as part of the implementation of the agenda, in consultation with Stakeholders	The target will be determined later as part of the Implementation of the agenda, consultation with stakeholders

3. Methodology

Air quality elements data from seven environmental recording stations spread around the Emirate of Ajman were used. They are considered the best as they are official and trusted data adopted by the local authority [24]. Data collected by these stations was used to monitor key gases such as sulphur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO), and ozone (O3), PM10, and PM2.5.

Additionally, weather parameters such as wind speed (WS), wind direction (WD), relative humidity (RH), and temperature (TEP) were also recorded as part of the comprehensive air quality analysis. collecting data on SO2, NO2, CO, O3, PM10, and PM2.5 and various weather parameters from these stations. The extensive dataset at hand offers a remarkable opportunity to gain valuable insights into the intricate dynamics of air quality within the Ajman Emirate. This wealth of information enables us to conduct a comprehensive analysis, delving into pollutant levels and their intricate relationship with various weather conditions.

The data was processed through Vista Data Vision (VDV), a mainstream centralised environmental monitoring system that includes air, water, noise, Odor monitoring, and measurement networks. Which tends to present real-time data, Graphs, alerts, mapping, video, and summary, as well as automated reporting, and analysed using Microsoft Excel. The stations' available equipment was intended to demonstrate real-time information about pollution levels at the strategic locations to record, analyse and evaluate the impacts of air pollution on the community and provide a continuous source of air quality data that was used in the comparison between the air quality data before in during covid 19 in which to confirm the theory that we could reach sustainable cities [25].

Advanced SWOT (Strengths, Weaknesses, Opportunities, & Threats) analysis [26], for Air Quality Strategy in the UAE: The basic SWOT framework's shortcomings were addressed by developing the advanced SWOT analysis. Strengths and weaknesses, or opportunities and threats, are equal in a straightforward SWOT analysis [27]. Due to its limitations, the SWOT analysis was only used as a guideline for future investigation. The Advanced SWOT analysis provides a far more reliable framework for prioritising factors. Some aspects may receive excessive or insufficient attention without prioritising, while the most important factors may go unnoticed [28]. As a result, the Advanced SWOT analysis gives decision-makers a greater understanding of their options.

3.1. Air quality management framework in sustainable cities

Three main Pillars are to construct this framework:

- Integrating Smart Technologies and Real-Time Data.
- Policy Integration and Regulatory Frameworks.
- Community Involvement and Public Awareness.

3.1.1. Integrating smart technologies and real-time data

To implement an AQM framework, smart technologies must be integrated to monitor and manage air quality in real time. Cities must invest in sensor networks capable of monitoring pollutants such as nitrogen oxides (NOx), sulphur dioxide (SO2), and particulate matter (PM2.5). Whenever there are high pollution levels, city authorities can adjust traffic flows or issue public health advisories based on real-time data, which can help them make informed decisions.

These sensors should collect data that can be made publicly accessible, which will enable citizens to make informed decisions concerning the activities they engage in daily. Air quality sensors are integrated with traffic management systems in cities like Copenhagen and Barcelona. During peak pollution hours, smart traffic signals manage congestion, limiting the number of vehicles allowed into city centres. This reduces air pollution, improves traffic flow, and reduces commuter travel times [22].

3.1.2. Policy integration and regulatory frameworks

A second pillar of the Air Quality Management framework is the development of robust policy frameworks to help support sustainable urban development. Economic growth and environmental sustainability can only be achieved through policies that limit emissions and enhance public health. Increasing the efficiency of transportation and industry is a means of improving air quality, as Narain (2024) suggests. Clearly defining emission standards and enforcing them through monitoring systems are essential to ensure long-term effectiveness. A major policy objective is to limit vehicle emissions.

In his book Babjak (2024), Babjak emphasises that by 2030, cities such as Oslo and Paris will ban gasoline and diesel cars. Additionally, improvements in public transportation can reduce traffic congestion and air pollution. Emissions from industrial sources should also be regulated. According to their report, clean technologies, renewable energy, and energy efficiency should be promoted. Industries can reduce emissions and adopt sustainable practices through tax credits and carbon pricing. According to Jerrett et al. (2024), carbon pricing is an effective method of encouraging pollution reduction in various sectors.

3.1.3. Aligning AQM strategies with the SDGs

Air Quality Management (AQM) strategies should align with the United Nations' Sustainable Development Goals (SDGs) to ensure they are integrated into global sustainability initiatives. In 2015, UN Member States adopted the Sustainable Development Goals, which include several air qualities, climate action, and urban sustainability goals. As part of AQM, Goal 11 (Sustainable Cities and Communities) calls for improving air quality and reducing environmental impact. Cities can reduce local pollution while contributing to global targets like reducing greenhouse gas emissions by adopting AQM strategies.

Long-term sustainability requires comprehensive, long-term strategies that don't compromise short-term gains. Pollution affects vulnerable populations, such as low-income communities. An aligned AQM strategy fosters economic growth, creates jobs, and attracts international funding. Furthermore, it enhances efforts to combat climate change and promote urban sustainability by facilitating knowledge sharing and best practice exchange between cities [29]. This alignment is illustrated in Table 3.

Table 3. Alignment of AQM strategies with relevant SDGs.

SDG	Alignment with AQM
Goal 3: Good Health and Well-being	Reducing air pollution improves public health outcomes.
Goal 7: Affordable and Clean Energy	Promoting renewable energy sources reduces industrial and vehicular emissions.
Goal 11: Sustainable Cities and Communities	Implementing clean transport and urban planning reduces city pollution.
Goal 13: Climate Action	Reducing emissions contributes to global climate change mitigation efforts.

3.2. Community involvement and public awareness

Air Quality Management (AQM) strategies require community involvement and public awareness. Participating in air quality issues enables residents to take ownership of issues and enhances transparency. Community involvement increases support and compliance with regulations, according to Jerrett et al. [30]. Educating the public about respiratory and cardiovascular diseases associated with air pollution is essential. When they understand these risks, people can reduce pollution exposure by using public transportation, reducing vehicle idling, and supporting clean energy initiatives [30].

Furthermore, technology promotes community engagement. Air quality data can be provided to residents in real-time through mobile applications. By notifying users of high pollution levels, apps can encourage people to limit outdoor exercise or use public transport instead of private cars, thereby reducing emissions [22]. With direct communication, air quality management efforts can get a lot better. A more informed and proactive citizenry is created by involving communities through such platforms, says [24].

4. Results and Discussion

4.1. Case study for air quality status in the UAE

To assess the current state of air quality and identify ways for sustainable urban development, this study aims to critically examine the strength factors of the Air Quality management strategy for the selected case study area. The concentrations of various pollutants, including nitrogen dioxide, sulphur dioxide, and particulate matter, were measured. In addition, it evaluated the effectiveness of policies that were implemented to curb air pollution. As a result, strategies were developed to reduce air pollution and enhance the air quality in the Ajman Emirates.

In Ajman-UAE, a case study provided insights into successful initiatives that improved air quality despite the COVID-19 pandemic. Industrial activities and other pollution sources were restricted in the city, which resulted in a noticeable improvement in air quality. The town also enforced a prohibition of private vehicles, while public transportation was promoted, which reduced vehicular traffic and air pollution. A notable decrease in particulate matter was achieved because of these measures. Moreover, the restriction on private vehicles resulted in a reduction in nitrogen oxide emissions, which further contributed to decreased air pollution. This improved air quality has positively impacted the well-being of the city's residents, providing a cleaner, healthier atmosphere. This initiative achieved dual benefits by promoting environmental sustainability and improving public health.

Figure 3 illustrates a comparative analysis of the most polluted gases (SO2 and NO2), which shows a significant reduction in both pollutants during the COVID-19 pandemic. A reduction of up to 50% has been recorded in some instances, mainly due to a reduction in human activities and industrial operations. Several factors contributed to this decline, including decreased emissions from vehicles, factories, and other human activities. Furthermore, reduced commuting and remote work contributed to this reduction in air pollution [25].

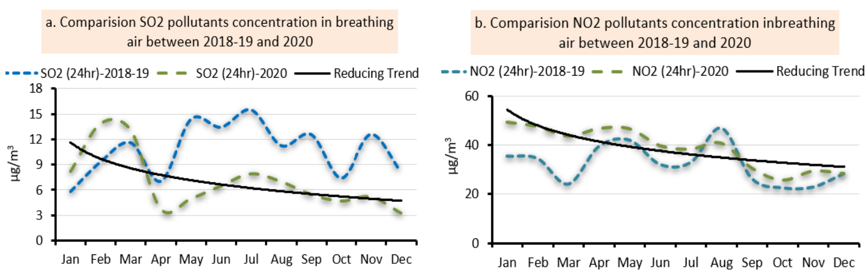

Fig. 3. Air quality data: a. SO_2, and b. NO_2 comparisons.

The concentration of CO reduced during the pandemic and again increased when the lockdown for transport stopped, as in the comparison shown in Fig. 4.

Further, the research demonstrates that gas trends vary both pre- and post-crisis, exhibiting a wide variety of percentage shifts. The study meticulously examines the graphs and highlights key gases detrimental to human health as well as crucial to fostering sustainable urban landscapes. Air pollution has a significant impact on health, contributing to the development of cardiovascular and respiratory disorders, in addition to increasing mortality rates.

This detrimental consequence of air pollution is primarily caused by human activities, such as the burning of fossil fuels and wood, industrial operations, vehicular traffic, and agricultural practices. In addition to carbon monoxide (CO), nitrogen oxides (NOx), sulphur oxides (SOx), and particulate matter (PM2.5, PM10), these perilous particulates are also known by other names. By restricting human movement and commercial activities contributing to air pollution, lockdowns provided researchers with a unique opportunity to obtain pertinent data. As a result of the reduction in activities, it was possible to collect more data, which allowed us to gain a deeper understanding of the effect of reduced human presence on air quality [25].

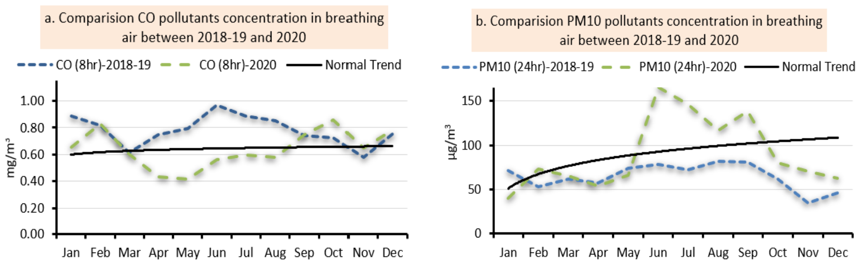

Fig. 4. Air quality data for a. Carbon monoxide, and b. Particulate matter comparisons.

Figure 5 shows a clear picture of the reduction in all the gases and PM10 per month, and it was clear that March and April 2020 had the most reduction. It was clear that the air quality improved during the pandemic as there was a reduction in most human activity during that period. As per those results, it is possible to reduce air pollution if we change our behaviour and actions through public transport, electric vehicles and clean industries.

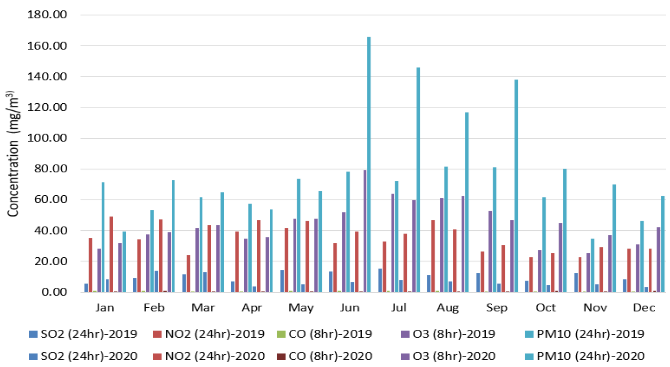

Fig. 5. Concentration of all elements of air quality compared between 2019 and 2020.

The lockdown during COVID-19 has caused a significant decline in the global economy, well-being, and transport movement. Seven environmental air stations in the Emirate of Ajman and the surrounding were used to collect data that shows the effects of meteorological variability and found declines in the population-weighted concentration of ground-level nitrogen dioxide (NO2: 40% - 60%) and inhaled particulate matter (PM2.5: 40%), (PM10: 12%) and CO concentrations, which lead that we could achieve future sustainable cities as we see during the covid time in all the countries worldwide.

The pandemic problem is an opportunity to consider how to build more resilient, inclusive, and sustainable cities. Naturally, a lot of the emergency measures could be changed once the health crisis is over. However, the epidemic will still affect the populace in terms of alternatives to the usual patterns of commuting and employment. Greater demand from people may also be fulfilled by the promise of more enticing cities, cleaner air, and sustainable infrastructure necessary for addressing the climate issue.

4.2. Strategic analysis

An in-depth SWOT analysis was conducted by experts from various fields to identify the most effective elements for air quality strategies [31]. The analysis began by examining strengths and weaknesses, followed by an evaluation of opportunities and threats to maximize potential benefits [32]. The strategies were then assessed for feasibility and effectiveness, resulting in a set of actionable strategies.

However, the general SWOT analysis has limitations, as it treats all factors equally, leading to possible over- or under-emphasis on certain factors [33]. To address this, an advanced SWOT analysis was proposed, where strengths, weaknesses, opportunities, and threats are identified and prioritized through a two-step process to ensure the most significant factors are emphasized.

To evaluate strengths and weaknesses:

- **Importance**: Rates their significance in the industry from 0.01 to 1.0, with total weights equalling 1.0.
- **Rating**: Scores each factor from 1 (minor) to 3 (major).
- **Score**: Combines importance × rating to prioritize actions.

For opportunities and threats:

- **Importance**: Rates external impact from 0.01 to 1.0.
- **Probability**: Scores likelihood from 1 (low) to 3 (high).
- **Score**: Importance × probability helps prioritise key factors.

During the research, a literature review identified the most common factors used in SWOT analysis, and an interview with experts confirmed ten factors to consider in advanced SWOT analysis. The factors and corresponding analysis results are shown in Table 4.

Successful factors highlighted in Table 4 resulting from the advanced SWOT analysis are the factors which are used to create strategies that the UAE can implement to achieve sustainable Air Quality strategic planning.

Table 4. Advanced SWOT analysis for air quality strategy in the UAE.

a. Strengths

Item and reference	Importance	Rating	Score
Existence of the environmental laws "Federal Law No. (24) of 1999 on the Protection and Development of the Environment" [23].	0.08	2	**0.16**
Federal Law No. (11) of 2006 amending provisions of Federal Law No. (24) of 1999 [23].	0.01	1	0.01
Cabinet Decree No. (12) of 2006 regarding Regulation Concerning Protection of Air from Pollution [23]	0.01	1	0.01
Ministerial Resolution 359/2015 regarding the technical requirements for air quality monitoring devices (applicable for quarries and crushers [23].	0.02	1	0.02
Newly Federal and local air quality strategies [34].	0.08	2	**0.16**
The existence of Air quality monitoring network [34].	0.08	2	**0.16**
Increasing green areas in UAE to achieve the set goals	0.04	1	0.04
Conducting the air inventory [35]	0.03	1	0.03
The EIA reports on all the new industrial projects [23].	0.03	1	0.03
National Green Agenda 2015-2030 [23]	0.01	1	0.01
National UAE Climate Change Plan 2017-2050 [23]	0.01	2	0.02
National Environmental Policy [23]	0.1	3	**0.3**

b. Weaknesses

Item and reference	Importance	Rating	Score
The limits and standards are not covering all the sources of pollution [36].	0.01	2	0.02
The limits and standards are not covering all the pollutions and their classification [37]	0.01	2	0.02
The energy production systems and the small percentage of sustainable energy [38]	0.1	1	**0.1**
The availability of air filtration systems for the industries [39]	0.1	1	**0.1**
Lake of air emission regulation on the restaurants add shishas cafes [37]	0.03	1	0.03
There is no national standard for the indoor air quality [37]	0.02	1	0.02
The construction and infrastructure projects are not specifying the air quality that will be affected or impact [32].	0.02	1	0.02
There is little motivation for people to use public transport and training is inadequate [40]	0.05	1	0.05
No engagement to use bicycles and the new electricity scoters [41].	0.02	1	0.02
Lack of estimates of economic and social costs of air pollution [41].	0.03	1	0.03
Lack of implementing new and optimal means of encouragement and punishment to prevent the emission of air pollutants from mobile and fixed sources [41].	0.03	1	0.03
Lack of public awareness about air quality [32]	0.08	1	**0.08**

c. Opportunities

Item and reference	Importance	Rating	Score
The existence of new technology for the monitoring and forecasting of pollutants [36]	0.09	2	**0.18**
The rapid improvement in the AI systems can help monitor and reduce the emission [36]	0.07	3	**0.21**
Global attention on the air quality and the reduction of the emissions [42].	0.02	2	0.04
Existence of valid international standards for vehicle production and fuel quality [43]	0.01	2	0.02
Existence of new automobile technology in the world Hybrid and electric vehicles [43]	0.08	2	**0.16**
Opportunities to use solar and wind energy [38]	0.01	2	0.02
The proper waste management systems used that reduces emissions [44]	0.1	2	**0.2**
Existence of researchers and researchers in the field of air pollution control [44]	0.03	2	0.06
Opportunities for CO_2 capturing and neutrality [45]	0.04	2	0.08
Intensive attention on green production technology and studies of green city components [46]	0.03	2	0.06
The new self-inspection and reporting that become mandatory on the establishment [47]	0.02	2	0.04

d. Threats

Item and reference	Importance	Rating	Score
Dependence on private cars and preference for large SUV models (with significantly higher emissions [48].	0.03	1	0.03
The non-allocation of suitable resources and/or maintenance for air quality monitoring, management, and air pollution mitigation [49]	0.04	1	0.04
The lack of support for large-scale industry investment in reducing emissions as they put it as a secondary priority [50]	0.1	1	**0.1**
Focus on industry as a key area of economic growth [51]	0.1	1	**0.1**
Identified gaps in the regulatory framework (in terms of outdoor air pollutants and source emission limits) and sectoral guidelines on emissions control/management [23].	0.03	1	0.03
Transboundary pollution (both in terms of international transboundary issues and those between emirates [52].	0.01	1	0.01
Natural pollutants, particularly the regional phenomenon of elevated particulate matter levels due to dry, often windy conditions, substantially impact the concentration of major outdoor air pollutants [23].	0.09	1	**0.09**
Inadequate communication and identification of clear roles and responsibilities within intra- and inter-emirate level stakeholders [53]	0.02	1	0.02
The awareness and acceptance of changing to green technology [54].	0.02	1	0.02
The time for acceptance the changes on the inspection and reporting [55].	0.01	1	0.01

4.3. Strategic framework

A framework is constructed to facilitate the implementation and evaluation of the strategies identified by the present analysis. Table 5 presents five categories in which the strategies are categorised. Planning, implementing, and evaluating each strategy that facilitates their implementation are outlined in the table. As shown in Fig. 6, these categories are organised into levels, and each level indicates the conceptual coverage of each strategy.

Table 5. Air quality continuous improvement strategic framework for sustainable cities

Category	Strategy	Planning	Implementation	Evaluation
Foundation	Education & Awareness	Conduct research on public awareness needs	Launch educational campaigns	Measure effectiveness through surveys and feedback
	Emirate Collaboration & Communication	Effective communication & collaboration	Foster collaboration between entities and regions	Review collaboration effectiveness and adjust approaches
Regulatory & Policy	Strengthen Regulations	Outline steps for standardisation	Address regulatory gaps and standardise emission control	Monitor compliance and adjust standards accordingly
	Address Regulatory Gaps and Standardisation	Assess existing regulations and identify gaps	Draft and enforce strict air quality regulations	Monitor compliance, assess impact, and adjust regulations
Technological Advancement	Forecasting Technology & Advanced Monitoring	Plan for monitoring system deployment	Install advanced monitoring tech and data collection systems	Analyse collected data for trends and forecasting
	Pollution Control through R&D	Research innovative pollution control technologies	Implement new technologies in industries and urban areas	Evaluate the effectiveness and efficiency of new solutions
Infrastructure & Systems	Comprehensive Waste Management Systems	Plan waste management strategies	Implement efficient waste collection and recycling systems	Assess waste reduction, landfill emissions, and recycling rates
	Transition to Renewable Energy	Develop a roadmap for renewable energy adoption	Incentivise and facilitate the shift to clean energy sources	Evaluate energy transition progress and benefits

Behavioural & Incentives	Public Transport and Green Mobility	Design plans for public transport enhancement	Improve public transportation, promote eco-friendly mobility	Analyse usage patterns, measure reduction in emissions
	Emission Reduction Incentives	Devise incentives for emission reduction	Implement incentives for industries and individuals	Measure emission reductions, assess incentive impact

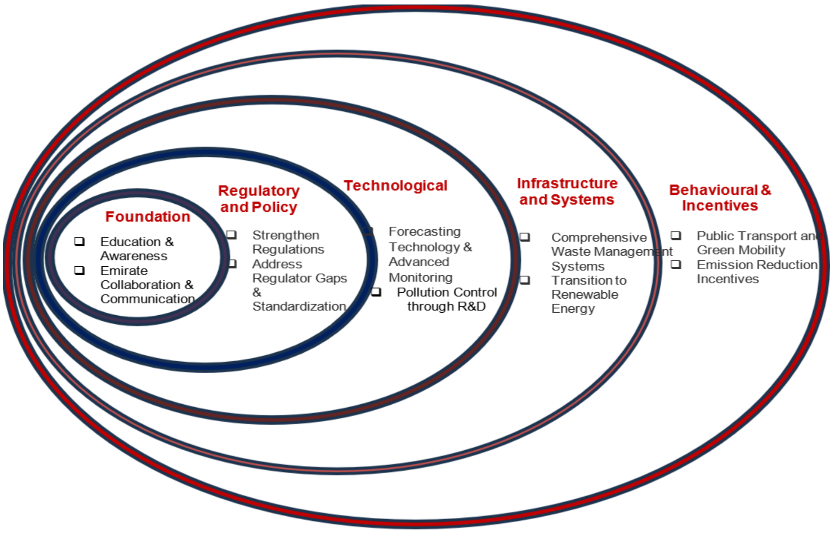

Fig. 6. Strategic system conceptual levels for sustainable air quality in the UAE (Constructed by Authors)

4.4. Key findings and Recommendations

In the context of sustainable development, it is crucial to consider various categories of strategies or initiatives that work together to achieve a common goal. The framework has four layers, each representing a different aspect that contributes to sustainable development; starting from the innermost layer labelled 'Foundation', we see points such as 'Education & Awareness' and 'Emirate Collaboration & Communication'. These elements form the basis upon which further strategies can be built. Education and awareness play a key role in fostering a mindset shift towards sustainability, while collaboration and communication among emirates ensure a unified approach towards sustainable development.

The other layers show the importance of strengthening regulations and addressing gaps in standards. Strong regulatory frameworks are essential to ensure compliance and drive sustainable practices across various sectors. Addressing regulator gaps and standardisation can streamline operations and promote consistency in sustainability efforts. Technological Advancement highlights the role of innovation in sustainability, with points such as 'Forecasting Technology' and 'Pollution Control;

technological advancements offer new solutions to environmental challenges and pave the way for more sustainable practices in industries and communities.

The 'Infrastructure and Systems' focuses on creating the necessary systems to support sustainable development. Points like 'Comprehensive Waste Management Systems', 'Transition to Renewable Energy', and 'Emission Reduction' underscore the importance of investing in infrastructure that promotes resource efficiency and reduces environmental impact, 'Behavioural & Incentives' layer addresses the human aspect of sustainable development. Encouraging behaviours like the use of public transport and green mobility, as well as providing incentives for sustainable practices, can drive positive change at the individual and community levels.

Ten recommendations were formulated based on the analysis and results of the research. Through careful consideration, best practices and international cooperation, governments can significantly improve air quality, protect public health, and transition towards a more sustainable future:

- Enhance regulatory framework
- Diversify the sources of energy
- Develop better monitoring systems
- Encourage sustainable urban planning
- Enhance the efficiency and cleanliness of transportation
- Promote public awareness
- Use artificial intelligence
- Invest in research and development (R&D)
- Strengthen international cooperation
- Provide training and education

5. Conclusions

By implementing a comprehensive strategic framework, this study emphasises the critical relationship between air quality and sustainable cities. Based on a SWOT analysis and an analysis of diverse urban environments, the study proposes a pathway to cleaner air in Ajman. The study suggests three pillars are integrating intelligent technologies and real-time data, Policy Integration and Regulatory Frameworks, and Community Involvement and Public Awareness. The first pillar advocates real-time monitoring and smart technologies to ensure rapid response to air quality issues. The second pillar focuses on developing regulatory frameworks aligned with global sustainability targets, such as SDG 11. Engaging communities, raising awareness about pollution risks, and encouraging sustainable behaviour are essential components of the third pillar.

This framework calls for the enhancement of regulatory structures, the diversification of energy sources, and the development of advanced monitoring systems. Research and Development using artificial intelligence for predictive capabilities, and sustainable urban planning is essential for long-term success. In addition, promoting public transportation and green mobility will contribute to pollution reduction and offering incentives to reduce emissions. Furthermore, the study recommends replicating environmental monitoring networks worldwide, strengthening international cooperation, and providing training and education.

With this transformative approach, air quality will be improved, and the future of cities and the environment will be healthier and more sustainable.

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