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A Comprehensive Platform for Air Pollution Control System Operation in Smart Cities of Developing Countries: A Case Study of Tehran

Amirhossein Kiyan[1], Mohammad Gheibi[2*], Mehran Akrami[3], Reza Moezzi[2,4], Kourosh Behzadian[5]

[1]Department of Engineering, Azad Islamic University, Karaj branch, Karaj, Iran
[2]Association of Talent under Liberty in Technology (TULTECH), Tallinn, Estonia
[3]Departamento de Ingeniería Industrial, Tecnologico de Monterrey, Puebla, Mexico
[4]Institute for Nanomaterials, Advanced Technologies and Innovation, Technical University of Liberec, Czech Republic
[5]School of Computing and Engineering, University of West London, London, UK
*** Mohammad.Gheibi@tultech.eu**

Abstract

Controlling air pollution in megacities is crucial from both a health and environmental perspective. Air pollution is a pervasive problem in these densely populated cities and must be effectively managed to promote sustainability. This study presents a framework for the intelligent management of air pollution control systems in developing nations. The framework was developed through the use of an expert agreement model involving five managers from Tehran. The results indicate that the Decision Support System (DSS) is equipped with calibrated sensors for monitoring air quality. Additionally, the concentration of air pollutants can be determined through the application of machine learning algorithms and the analysis of historical data. Rapid response methods are then applied to mitigate the acute and chronic effects of air pollution. The DSS also incorporates citizens' feedback to evaluate the effectiveness of air pollution control measures. Implementing this model in developing nations' smart cities can help achieve several of the United Nations' Sustainable Development Goals (SDGs), such as good health and well-being, sustainable cities and communities, climate action, and life on land.

Keywords: *Air pollution; Smart cities; Developing countries; Control System; Sustainability*

INTRODUCTION

Air pollution has become a critical issue in both developed and developing countries, and the rapid growth of urban populations has only compounded the problem in many cities [1]. Therefore, having access to up-to-date information on changes in air pollution is imperative for maintaining healthy living conditions. In recent years, the calculation and prediction of air quality has become a significant field of research in environmental engineering [2]. As air quality can have a direct impact on human health, evaluating its index is a critical aspect of environmental engineering. In 1999, the United States Environmental Protection Agency (EPA) established the Air Quality Index (AQI) to report on the unique and harmful effects of ozone, particulate matter 2.5 and 10, carbon monoxide, sulphur dioxide, and nitrogen dioxide. The AQI provides a useful and informative indicator that reports the combined impact of air pollutants at monitoring sites [3].

To raise public awareness about air pollution, the Tehran Environmental Pollution Administration follows the EPA's air quality index, which includes sub-indices for ozone, PM10, PM2.5, carbon monoxide, sulphur dioxide, and nitrogen dioxide. The air quality index serves as an easily understandable indicator of air quality and alerts the public to the health risks associated with air pollutants [4].

Several studies have been conducted on the existing air quality indicators, and the development of forecasting models for daily AQI has been recognized as a critical issue. Choosing the right model that accurately predicts future AQI is essential. Gaussian dispersion models are widely used in air pollution studies [5]. However, analytical models for pollutant dispersion can be complex and challenging, as they require a set of environmental data and the identification of sources, and can suffer from large errors due to oversimplification of theories. Statistical models, on the other hand, can simplify the prediction of pollutant concentration values within a reasonable range and are being used in different regions to identify local meteorological conditions that influence air pollutant concentrations [6].

Studies have also been conducted on the relationship between weather conditions and high pollutant levels. These studies typically provide qualitative or semi-quantitative results and can explain the relationship between pollutants and meteorological conditions. Recent advancements have led to the improvement of linear regression models for pollutant prediction, and neural networks have been utilized to predict weather patterns. However, previous studies on daily air index forecasting in China have shown that regression forecasting methods, such as Support Vector Regression (SVR), may not accurately predict air quality indices [7].

In addition, he showed that the AQI is strongly related to meteorological changes. Some researchers used Auto-Regressive Integrated Moving Average (ARIMA) and multiple linear regression (MLR) models to forecast weather in Delhi. To determine the function in a more precise model, Engel proposed the model auto-regressive conditional heteroscedastic (ARCH) as well as the generalized auto-regressive conditional heteroscedastic (GARCH) model in 1982. After that, other researchers use these time series models to find better forecasting models that are more accurate [8]. By converting a related model into a short-related model, computational complexity can also be obtained for this model. Therefore, the GARCH model can improve the forecasting model. There are many forecasting models and some of them are in use, the accuracy of the models is not enough and the models must be needed to improve the accuracy of the model. Research items applied several personal forecasting models to improve the forecasting model. The improved model the autonomous model is a combination of two or three methods such as ARIMA, GARCH, and bootstrap [9].

Air pollution and its impact on human health has become a major concern globally, and as such, accurate and timely information on air quality changes is critical. One of the ways to evaluate air quality is through the use of the Air Quality Index (AQI). In recent years, the calculation and prediction of AQI have become an important area of study in environmental engineering, and researchers have been working to develop more accurate models to forecast AQI.

The relationship between air quality and meteorological changes has been the subject of numerous studies, with some showing that the Air Quality Index (AQI) is strongly correlated with meteorological factors. Researchers have attempted to improve the accuracy of AQI forecasting models, with several studies employing the Auto-Regressive Integrated Moving Average (ARIMA) and multiple linear regression (MLR) models to forecast air quality in Delhi. Engel (1982) proposed the use of the auto-regressive conditional heteroscedastic (ARCH) and generalized auto-regressive conditional heteroscedastic (GARCH) models as a more precise method for forecasting AQI. These time series models have since been used by other researchers to develop more accurate forecasting models [8]. The GARCH model can reduce computational complexity by converting the model into a short-term related model, leading to improved forecasting. Several studies have proposed improved models, such as the combination of ARIMA, GARCH, and bootstrapping [9]. Despite the numerous forecasting models in use, the accuracy of these models still needs improvement, and ongoing research efforts are focused on developing even more effective models.

A number of researchers have demonstrated the potential for accurate prediction of air quality values through the utilization of regression models. By combining multiple regression (MLR) and principal component analysis (PCA), a more robust predictive model can be created. PCA has been utilized in previous studies to examine the temporal and spatial distribution of sulphur dioxide (SO2) in urban areas. Researchers have combined ARIMA and PCR models to predict daily AQI levels in Delhi and found that meteorological factors, such as wind direction, wind speed, daily average temperature, and daily rainfall, play a crucial role in accurate prediction through PCR [10].

Furthermore, two models have been proposed for the prediction of PM10, SO2, and ozone (O3) concentrations: the Advanced Air Pollution Forecasting Model (e-APFM) and the Air Pollution Forecasting Model (APEM). These models were designed to provide more accurate predictions of air quality levels and have been the subject of numerous studies [11].

Historical data, including weather forecasts, meteorological variables, and pollution levels for a significant number of points in time, are used as inputs in the Advanced Air Pollution Forecasting Model (APFM). Researchers first focus on evaluating the performance of forecasting methods, followed by the development of new forecasting methods. This model is useful when there is limited data available, and as a result, the e-APFM methods were found to have a smaller difference between observed and predicted concentrations compared to APFM. The process of combining different and independent variables and creating specific conditions to model and predict future results is one of the key features of regression models and provides the potential for decision-making support in the field of air quality management. To accurately define the sequential patterns of air quality zones, it is important to combine the time-series correlation rules and determine how conditions may change due to the occurrence of random factors [10],[11].

The interpretation and understanding of the results obtained from regression models is crucial in decision-making processes. Therefore, it is important to present the results in a way that makes it easy for users to understand and manage them in different conditions. To achieve this, visualizing the results through spatial and temporal zoning has been proposed as an effective method. This can provide decision support in air pollution management, which requires a series of consecutive decisions to be taken, and can determine the success level of the goals being pursued. To provide a comprehensive overview, various sections including State of the subject, Objectives, Algorithm, proposed locations for implementation, and Conclusion have been presented in previous studies [10],[11].

State of the subject

The term "natural disasters" refers to events caused by natural phenomena that have created major problems and challenges for human societies over the centuries [12]. These events demonstrate the vulnerability and fragility of human economic development to the forces of nature. Natural disasters, such as earthquakes, droughts, volcanic eruptions, forest fires, and atmospheric phenomena, can have devastating consequences on human lives, resources, and infrastructure. Despite advances in safety and prevention, natural disasters continue to pose a threat to communities worldwide.

Therefore, it is essential to think ahead and plan for the potential occurrence of natural disasters. One area in which this type of planning is important is in the management of air pollution. To effectively reduce air pollution levels, it is necessary to determine in advance the areas with high levels of pollution and to predict the amount of air pollution that may occur. This requires accurate forecasting methods and predictive models.

The use of forecasting and predictive models in the management of natural disasters and hazards is critical in improving safety and reducing the impact of these events. By predicting potential disasters and accidents, suitable solutions can be developed and implemented to mitigate the damage they may cause. The importance of future research in this area lies in its ability to scientifically manage preparedness, prevention, and reduction of disaster-related harm through accurate predictions and appropriate solutions.

GOALS

The objective of this project is to forecast the air quality index (AQI) in the city of Tehran using an artificial intelligence algorithm. The prediction of AQI will provide the authorities with valuable information to make informed decisions and take necessary measures to reduce air pollution and minimize its negative impacts on the health and well-being of the citizens. The project aims to determine the AQI in different areas of Tehran for the upcoming days, which will help in avoiding the need to build new sites in the city and reduce associated costs. Additionally, the project seeks to evaluate the effectiveness of air control policies in Tehran through multidimensional decision support tools. The goal is to provide a scientific approach to manage air pollution and prepare for potential air quality issues in the future.

THEORETICAL FOUNDATIONS

Sources of air pollution

The sources of pollution in cities can be broadly categorized into stationary and mobile sources [13].

1. Stationary sources, such as industrial units, refineries, commercial and service units, and households, are a major contributor to city pollution.

2. Meanwhile, mobile sources, primarily motor vehicles, also contribute significantly to pollution in cities. Additionally, other factors such as natural and artificial resources are also contributing to pollution levels, as depicted in Fig. 1.

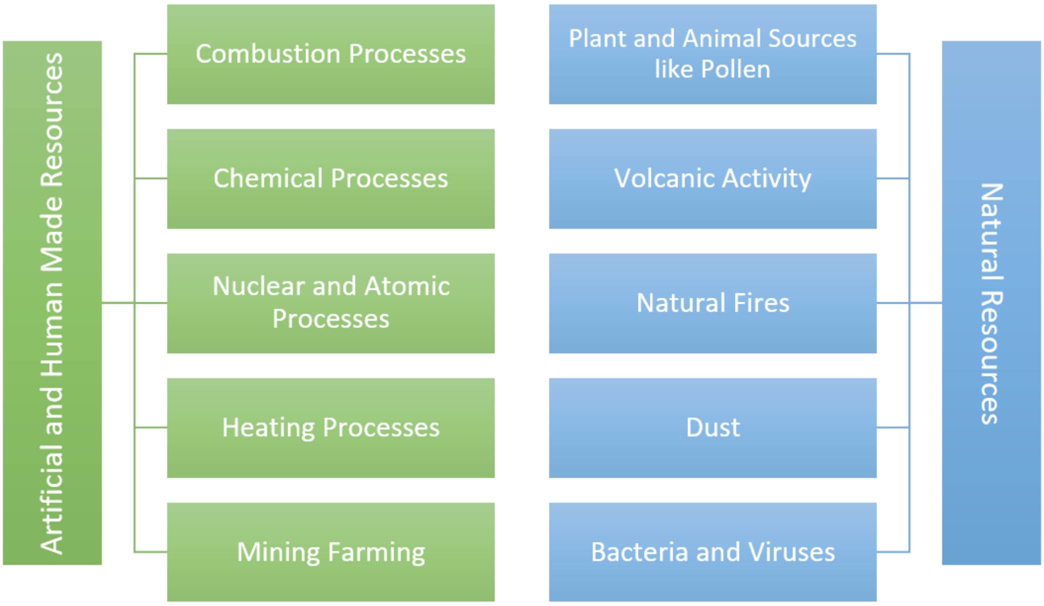

Fig. 1. Classification of air pollution sources

Air pollutants and their effects

Air pollutants can be divided into two main categories based on their physical state: gases and particles. Gaseous pollutants include, among others, carbon monoxide, sulphur dioxide, hydrogen sulphide, nitrogen oxides, hydrocarbons, and photochemical oxidants. Particulate pollutants encompass a diverse range of particle sizes and chemical compositions. In this article, we will examine several of these pollutants and their impacts on human health.

Sulphur oxides

Sulphur oxides, including sulphur dioxide and sulphur trioxide, are a type of air pollutant. Sulphur dioxide makes up the majority of sulphur oxides at about 98%. This colourless, non-flammable gas is invisible, but can be detected by the human sense of smell at concentrations above 3 parts per million (ppm).

The majority of sulphur oxides are produced by human activities, such as the combustion of fossil fuels that contain sulphur. These activities include burning fossil fuels for heating, as well as industrial processes such as power generation and non-combustion industries like copper smelting, sulphurous mineral smelting, sulfuric acid production, cement production, and to a lesser extent, transportation [14].

Sulphur dioxide gas primarily affects the respiratory system. It has a strong, unpleasant odour and is highly soluble in water, leading to most of it being absorbed by the upper respiratory system and dissolving in the mucous membrane of the pharynx and larynx. Only a small portion reaches the air sacs. The moist mucous lining of the upper respiratory system absorbs around 95% of the sulphur dioxide and transfers it into the bloodstream.

When sulphur dioxide concentrations in the air increase, it can have harmful effects, particularly on vulnerable populations like the elderly or those with pre-existing respiratory conditions or shortness of breath. The combination of sulphur dioxide with air humidity increases its negative impact on health. When sulphur dioxide combines with water vapor, it forms sulfuric acid, which can be harmful to inhale. This results in increased waste [15].

Nitrogen oxides

There are seven identified oxides of nitrogen, with nitrogen monoxide and nitrogen dioxide being the most significant in terms of pollution. Nitrogen monoxide is the most prevalent of the nitrogen oxides in the air and has no known harmful effects on human health at normal atmospheric concentrations. However, when nitrogen monoxide oxidizes to nitrogen dioxide and reacts with hydrocarbons in the presence of sunlight, it contributes to the formation of photochemical smog. Furthermore, nitrogen dioxide combined with hydroxyl radicals leads to the creation of nitric acid, which can fall to the earth's surface as acid rain.

Compared to other air pollutants, nitrogen oxides are more challenging to control and reduce. Studies have shown that while controls on the combustion of cars have significantly reduced the levels of carbon monoxide, the situation with nitrogen oxides has not improved, and in some cases, has worsened [16].

The effects of nitrogen dioxide on human health are primarily related to the respiratory system. At atmospheric concentrations, nitrogen dioxide can cause irritation and has been linked to chronic obstructive pulmonary disease (COPD). The extent of its effects on humans depends on both the concentration of the gas and the duration of exposure. Prolonged exposure to nitrogen dioxide can result in respiratory distress, a heightened sense of smell, lung blockage, and in extreme cases, death. This gas is particularly harmful for vulnerable populations such as the elderly and children, who are at a higher risk of developing bronchitis as a result of their long-term exposure to the gas [17].

Carbon monoxide

Carbon monoxide (CO) is an odourless and colourless gas that can be toxic and lethal in high concentrations. At lower concentrations, it can lead to symptoms such as fatigue, headache, dizziness, and convulsions. This gas is produced as a result of incomplete combustion and is a significant contributor to air pollution. Approximately 60% of total CO emissions are from car exhaust, particularly in densely populated urban areas where 95% of CO emissions originate from transportation. CO levels tend to be highest during cold months or inversion conditions when pollutants are trapped in lower, warmer layers. The combustion of gasoline, natural gas, coal, and oil, as well as some industrial processes, contribute to the emission of CO [18].

The presence of carbon monoxide in the bloodstream interferes with its ability to deliver oxygen to various cells and tissues throughout the body, which are essential for normal functioning. This toxic substance can be particularly dangerous for individuals with heart or circulatory problems, or who have suffered damage to their respiratory system. Exposure to high levels of carbon monoxide can lead to a range of negative effects, including reduced visibility, decreased work capacity, mobility, cognitive abilities, and overall ability to perform everyday tasks [19].

Suspended particles

Suspended particles in the air consist of a mixture of solid particles and liquid droplets [20]. Some particles are large enough to cause smoke or heavy fog, while others are so small that they can only be observed under an electron microscope. Both fine particles (diameter less than 2.5 microns) and larger particles (diameter greater than 2.5 microns) are released into the air from various sources, including mobile sources like vehicles, stationary sources such as power plants, and natural sources. Fine particles (PM2.5) are primarily produced from the combustion of fuels in cars, power plants, industrial facilities, and household appliances like stoves. Larger particles (PM10) often come from activities such as car travel on unpaved roads, handling of materials, milling operations, soil erosion, and wind-blown dust. Fine particles can also result from the reaction of gases like nitrogen oxides, sulphur dioxide, and volatile organic compounds with other compounds in the air. The composition of particles varies based on the location, season, and climate. While one may think that particles would fall to the ground quickly due to gravity, this is not always the case with fine particles. The settling speed of particles increases with the square of their diameter, so the fall of small particles is so slow that they remain suspended in the air for extended periods unless they collide with another particle and adhere to it [21].

Studies indicate that elevated levels of suspended particles and sulphur oxides in the air have led to a significant increase in hospital admissions. Exposure to air pollution has been linked to various respiratory illnesses, including infections of the upper respiratory system, heart diseases, bronchitis, shortness of breath, and pneumonia. Some suspended particles are also toxic and can cause serious health problems. For instance, carbon-based particles, specifically cyclic aromatic compounds, are potentially carcinogenic. Inhaling fine particles with a diameter greater than 2.5 microns can lead to the accumulation of these particles in the respiratory system, increasing the risk of asthma. Furthermore, exposure to suspended particles can also cause vision loss [22].

Weather parameters affecting air pollution

The term "weather" refers to the current atmospheric conditions at a specific time and location. It is influenced by various processes and changes in the atmosphere, and can be affected by several factors. Over time, the most common weather patterns in a certain region become that region's climate. Climate is the long-term average of the weather in a specific place.

The elements of climate, such as temperature, pressure, and solar radiation, can be influenced by climate factors, such as altitude, direction, and cloud cover. Interactions between these elements and factors can affect the formation, movement, concentration, or removal of pollutants in the air. Some pollutants are produced through photochemical reactions and can impact both local and global climate conditions. Poor air quality can result in reduced visibility, increased precipitation with acidic compounds, and the urban heat island effect, which occurs when air quality changes in cities. To better understand these relationships, the study of climate often involves diagnosing the quality of these factors and elements through investigation and case studies [23].

Temperature

Temperature is one of the key components of weather [24]. The uneven distribution of the sun's energy across the earth's surface results in varying temperatures, which in turn influence other elements of the atmosphere. Factors such as seasons, day length, ocean currents, wind, latitude, land masses, altitude, cloud cover, and slope orientation can cause temperature changes. The relationship between altitude and temperature has a significant impact on the movement of pollutants. When temperature inversions occur, it causes atmospheric stability, inhibiting the vertical movement of pollutants and reducing wind energy, thereby preventing the spread of pollutants both vertically and horizontally. In certain situations, changes in the air temperature profile brought on by various forces can disrupt the natural movement of air, leading to what is known as air stability. Stable air has a tendency to increase the concentration of pollutants in the atmosphere [25].

Wind flow

Wind flow, both in terms of speed and direction, is a crucial factor in the study of weather. Hurricanes boast the highest wind speeds on Earth, with speeds reaching 89.54 m/s. Wind speeds below 1 m/s are generally not felt, and most weather stations report calm conditions for wind speeds below 1 meter per second due to the limitations of measuring such low winds with anemometer equipment. The wind speed increases with height in most parts of the troposphere, due to the slowing effect of ground friction. The height of 500 meters above the ground, where wind reaches its frictionless speed, is known as the gradient. Areas closer to the ground, where ground friction dominates, are referred to as the Earth's boundary layer [26].

The surface wind speed is heavily influenced by the connection between the boundary layer and the wind gradient. When the atmosphere is stable or has a temperature inversion, there is limited vertical motion, leading to weak coupling between the boundary layer and the wind gradient. This results in low wind speeds at the Earth's surface. On the other hand, instability leads to increased wind speeds, but this increase is self-limiting as it removes the source of instability. Strong winds provide for better mixing in both the horizontal and vertical directions, and winds with speeds greater than 6 meters per second can shift a stable atmosphere to a neutral state.

The prevailing wind direction is the direction from which wind blows most frequently, and it doesn't necessarily have to be the direction of the strongest wind. Topographical factors such as coastal winds, onshore winds, and local mountains and valleys can determine the wind direction [27]. Local winds at the surface are also influenced by the direction of main storms. For example, in deep valleys, diurnal variations, including cross-valley winds during the day and precipitation during the night, dominate other factors and often dictate local flows in the absence of large storms or fronts. In other areas, winds may be seaward and landward, depending on the absence of large storms. These breezes can control wind direction during low wind and clear sky conditions.

In conclusion, high-speed winds not only create atmospheric instability but also move pollutants and reduce their concentration at ground level [28].

Humidity

Humidity refers to the amount of water vapor present in the air. Although water vapor is only a small fraction of the entire atmosphere, with an average of less than 2% of the total air mass, it is a critical component in understanding weather conditions. This is because the humidity of the air at the ground level influences the temperature of that area. The composition of the atmosphere near sea level is relatively consistent from one location to another on the earth's surface, and the amount of water vapor remains relatively stable, ranging from zero to a maximum of 5%.

Water vapor plays a crucial role in the energy balance of the atmosphere and the earth, for instance, it reflects short-wave solar energy and absorbs long-wave terrestrial energy, thereby impacting the thermal changes of the earth. Additionally, water vapor helps transfer atmospheric energy from one place to another through the processes of evaporation and precipitation [29].

Dew point

The temperature at which the air becomes saturated with water vapor is referred to as the dew point [30]. This process occurs through cooling without adding any water vapor. As the air cools, condensation occurs and water particles form. Dew typically forms in the early morning or evening when temperatures drop, and it requires clear, windless weather conditions. There are two ways in which dew forms: descent and ascent. When wind blows water vapor from the atmosphere to the ground and it condenses on cold surfaces, dew descends. If the wind is calm (with a speed less than 0.5 m/s) and water vapor rises from the ground, dew will form on nearby cold surfaces such as grass through ascent. In meteorology, the difference between dry and wet temperatures is used to determine the dew point. This is done by measuring the dry air temperature with two thermometers, one dry and one wet, and then using existing tables to calculate the dew point temperature. Dew plays a significant role in the growth of plants in desert regions, although it is often not considered in discussions of fog and hydrology.

Precipitation

Precipitation is any form of condensed moisture that falls from the atmosphere to the earth's surface. It forms when moist air rises to a certain height and reaches its saturation point due to cooling, leading to precipitation in the cloud. Not all clouds can produce precipitation, as it requires the water droplets, ice pieces, or crystals to become large enough to overcome the buoyancy and lifting forces of the air. Precipitation can take the form of liquid (such as rain and dew), solid (such as snow and hail), and gas (fog) [31].

Rainfall plays a significant role in cleaning the atmosphere of pollutants. As the precipitation descends, it removes suspended particles and water-soluble gases in the air, returning them to the ground. The efficiency of this cleaning process depends on several factors such as the size of the rain and snow grains, the speed of their fall, the intensity of the rain, the duration of the rain, and the number of suspended particles and impurities in the air [32].

Evaporation

The transformation of water into vapor is called evaporation. This process can occur from open bodies of water, moist soil, or through the transpiration of plants. Despite its significance in determining climate classifications, measuring actual evaporation is a challenging task in meteorology. The rate of evaporation in a region is influenced by various factors including solar radiation, atmospheric humidity, wind speed, and air temperature. In Iran, evaporation is typically measured using Class A evaporation pans at weather stations and is expressed in millimetres [33].

Pressure

Air pressure refers to the force exerted by air on the earth's surface. At the surface of the open sea, it is measured as the equivalent weight of a 76 cm tall column of mercury and is recorded in millibars (hpa). The standard air pressure at the surface of the open sea is around 1013 hpa, or one atmosphere, per square centimetre. As air density decreases with altitude, air pressure also decreases, though the change is not consistent with the increase in altitude [34]. Generally, air pressure decreases by about 12 hpa for every 100 meters of elevation up to 1500 meters above the ground. Above this height, the rate of pressure reduction slows. Air pressure dispersion is a critical aspect of weather patterns as it influences other weather elements. Meteorologists first identify the pressure distribution pattern on the ground and then study other elements based on this pattern. High-pressure systems are typically linked to clear skies, gentle winds, and a stable atmosphere, and if a system remains in one area for a long period, air pollutants can accumulate. Low-pressure systems, on the other hand, are related to wind, atmospheric instability, and rain, so the chance of pollutant accumulation is lower [34].

Importance of AQI

Air pollution has a negative impact on human health and breathing. Air quality can change based on daily and hourly weather conditions, making it important to monitor and evaluate air quality in large cities. The AQI (Air Quality Index) is used to report on the quality of the air in real-time and provide information to the public about the health effects of air pollution [35]. The AQI is calculated based on five main air pollutants: nitrogen dioxide, particulate matter, carbon monoxide, ozone, and sulphur dioxide. To help people understand the results, the AQI is divided into six categories, each relating to different levels of human health [36]. These categories are:

Good: AQI values from 0 to 50 indicate satisfactory air quality and no threat to human health, indicated by the colour green.

Moderate: AQI values from 51 to 100 indicate acceptable air quality but with some health considerations for a limited number of people, indicated by the colour yellow.

Unhealthy for Sensitive Groups: AQI values from 101 to 150 indicate that some people may experience health effects, indicated by the colour orange.

Unhealthy: AQI values from 151 to 200 indicate that anyone may experience complications, with more severe effects for sensitive groups, indicated by the colour red.

Very Unhealthy: AQI values from 201 to 300 indicate dangerous air quality and risk to human health, indicated by the colour purple.

Hazardous: AQI values higher than 300 indicate an emergency and a great risk to human health, indicated by the colour brown.

The categorization of AQI computations and outcomes is shown in Table. 1.

Table1 .The relationship between AQI and hygienic level and its corresponding colours

Colours	Hygienic level	AQI
Green	Good	0-50
Yellow	Moderate	51-100
Orange	Unhealthy for Sensitive Groups	101-150
Red	Unhealthy	151-200
Purple	Very Unhealthy	201-300
Brown	Hazardous	More than 300

The AQI index formulation is illustrated according to Equation 1 and Fig. 2.

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}(C_p - BP_{LO}) + I_{Lo} \tag{1}$$

Where, I_p = AQI for pollutant P

C_p = measured concentration for pollutant P

BP_{Hi} = breaking point that is greater than or equal to C_p

BP_{Lo}= breaking point which is less than or equal to C_p

I_{Hi}= value of air quality index coordinated with BP_{Hi}

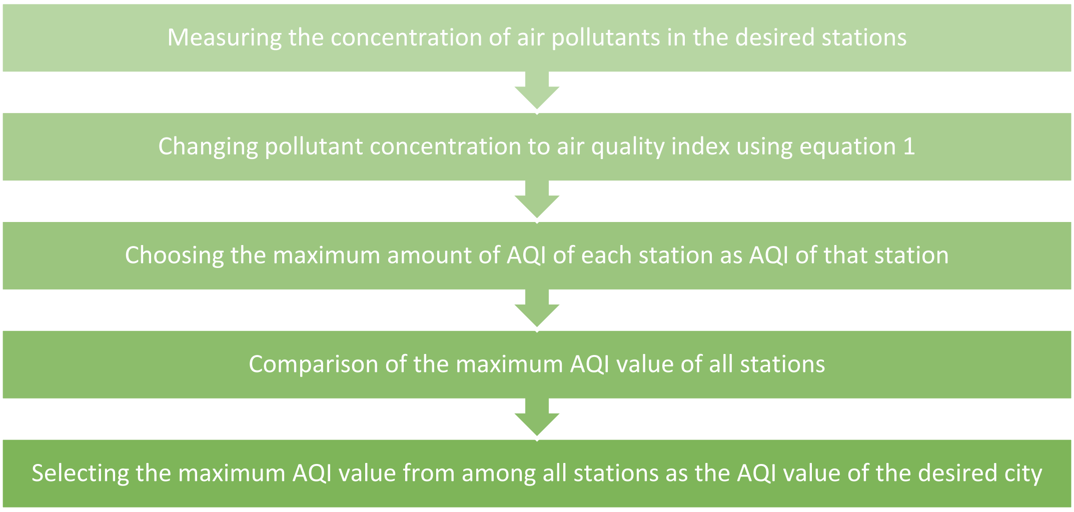

Fig. 2. How to calculate the air pollution quality index for a city.

SUGGESTED MODEL

The goal of this investigation is to design air pollution control systems for smart cities. In the first step, experts' idea agreement is achieved through subscribed special meetings to present the air pollution Decision Support System (DSS). The experts' committee comprises five managers of Tehran City in the field of air pollution control.

Data Analysis and Prediction

In this project, data analysis begins by identifying and extracting the data. After sorting and making the data understandable, prediction algorithms are applied to predict air pollution, precipitation, and temperature. Next, neural network spatial modelling is used to predict the results of the implementation of air pollution control strategies in the Tehran metropolitan area.

Steps

Collecting and Studying Sources

This section involves collecting sources related to the subject, reviewing methods used around the world, and selecting forecasting models and the most appropriate air pollution control strategies based on existing conditions and structures in each area of the city.

Collection of Modelling Data

The primary data for predicting the air AQI includes meteorological data and AQI values of the past years. Accuweather.com and Meteorological Organization will be used to receive meteorological data (including wind speed, rainfall, and high and low temperature), which has acceptable and reliable accuracy. AQI values related to previous years will be received from the website of the air quality control company.

Modelling and Forecasting

In this section, AQI, temperature, and precipitation are modelled daily using models such as ARIMA, PCR, and GARCH. The stages of time series modelling involve the initial analysis, determination of the model order and parameter estimation, and prediction.

Prediction of Air Pollution Control Strategy

This section involves clustering air pollution control strategies based on criteria and weighting processes and evaluating the tables of each strategic plan in the defined urban areas. The expected level of pollution in each zone is modelled based on relationships and laws, and the prediction models of time series derived from the results of the overlap of grid cells of the reference location include information on the density of pollution in each zoned cell. The validation process of the model results in the implementation of strategic pollution control programs as a system.

Clustering of Selected Strategies

This section involves compiling the criteria value classification table using evaluation matrices and adjusting the extracted numbers on the information layers of the spatial analyst. The strategies are in the form of spatial clusters and are classified according to the criteria.

Zoning and Model Design

This section involves implementing floating patterns of population behaviours, the influence of climatic factors, and dynamic processes of linear, surface, and point contamination of random factors using visualizing techniques of spatiotemporal zoning of the environment.

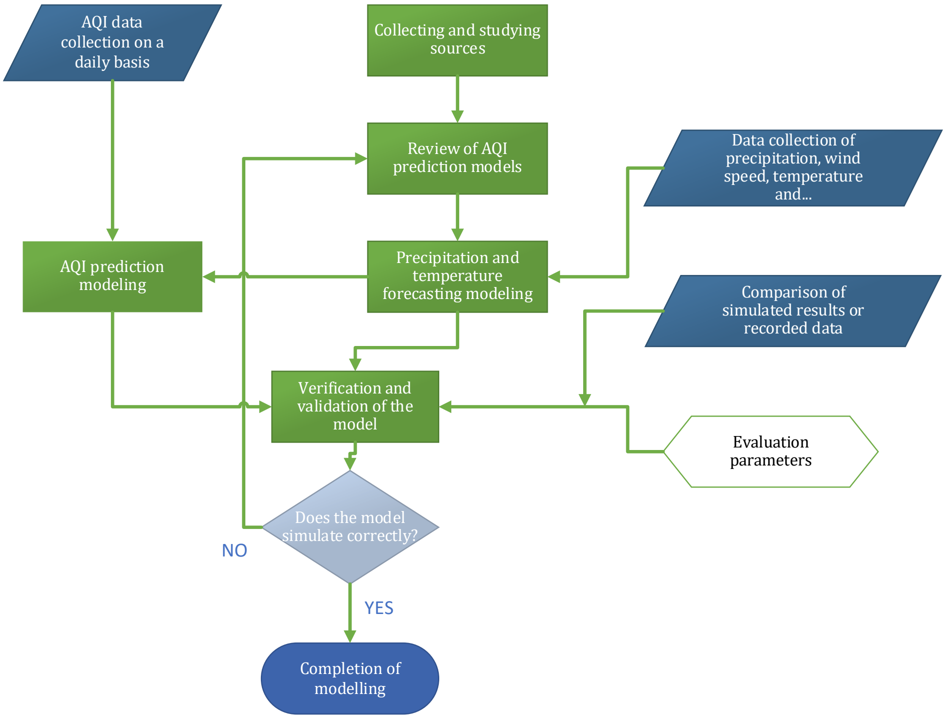

Fig. 3. Carrying out modeling steps for forecasting precipitation, temperature, and AQI.

The structure of the prediction system was presented in Fig. 3, while Fig. 4 outlines the framework for the air pollution control system and decision-making. The suggested framework consists of three main components: infrastructure, system, and management. The infrastructure and system sections comprise two parallel phases: (1) data screening, standardization, and decision-making based on local conditions and (2) data evaluation, spatial modeling, and time series analysis. The management section involves selecting the best-validated strategies for air pollution control under the supervision of expert presence.

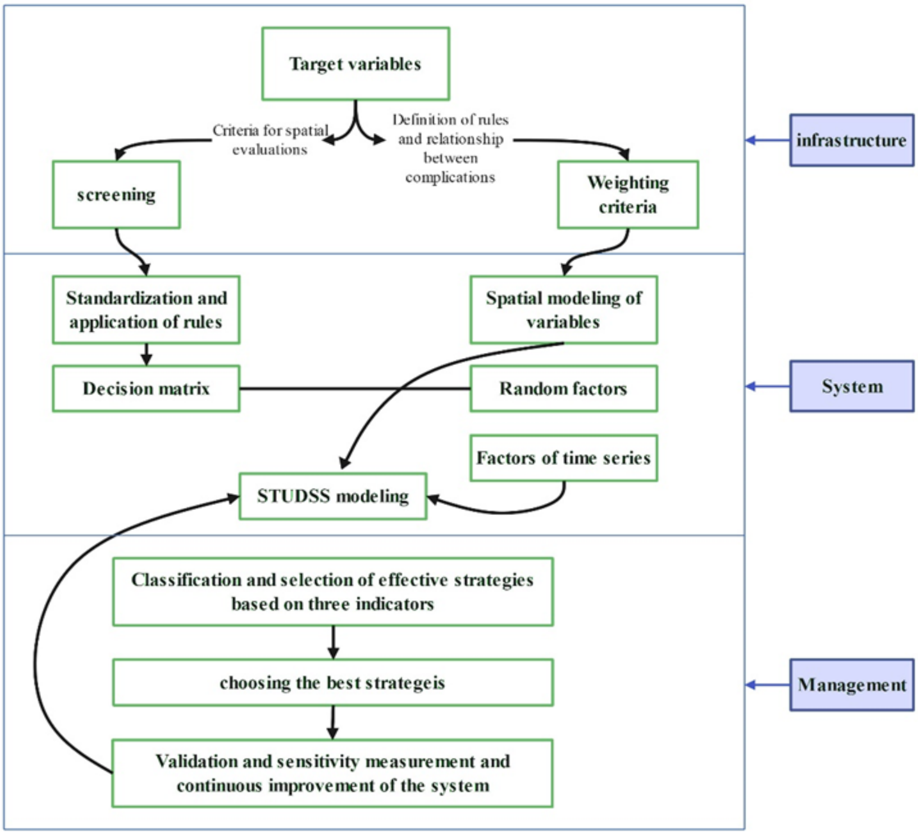

Fig. 4. Design of spatial neural network decision support system - air pollution control

The project follows the process illustrated in Fig. 5 and aims to develop a decision support system (DSS) [37], [38] for air pollution control in smart cities of developing countries. The sensor network data is assumed as a monitoring section, while other environmental features such as precipitation, solar radiation, wind speed, direction, temperature, and traffic load are considered as model inputs. Machine learning (artificial intelligence) models are employed for air pollution estimation, and decision-making processes are considered the control section of the DSS [39].

The input section includes data on AQI, all pollutants, and environmental factors. The Processor section employs a neural network and time series to predict AQI and other pollutants. Decision-making processes select the best scenario based on the output, while Real Decision Making compares the results to achieve the best outcome. This cycle is repeated to control air pollution effectively.

The prediction of air pollution levels not only informs decisions to reduce pollution but also allows the public to be informed about areas with the worst pollution levels. Therefore, people can avoid traveling in those areas, leading to better public health outcomes.

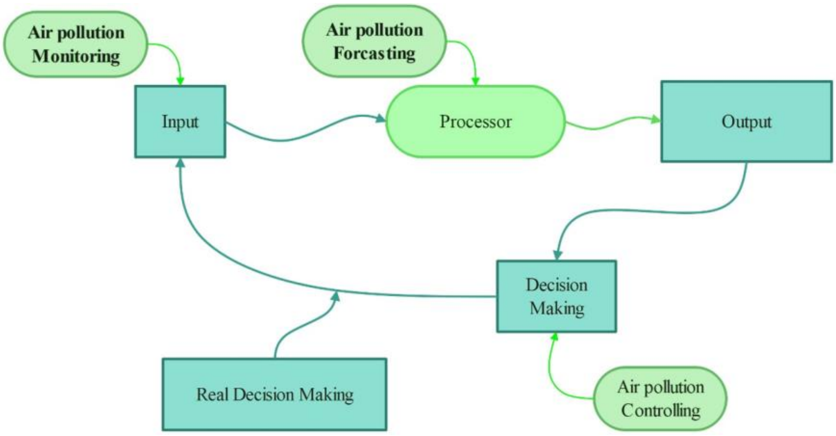

Fig. 5. Summary of the project's steps.

The last section of the research presents a conceptual model for implementing the suggested DSS in developing country megacities, as shown in Fig. 6 [40]. The main driver for the dashboard is to inform citizens about the adverse effects of air pollution on human health. This can raise awareness in communities and prompt citizens to demand clean air as a social demand from authorities. The model was developed through sequential meetings with experts invited for this research.

The executive activities for the DSS implementation involve enhancing sensor equipment, implementing a soft-computing platform, and establishing a people-based feedback system to assess citizens' satisfaction with the air quality in the city. By involving citizens in the feedback system, their needs and demands can be better addressed, leading to more effective air pollution control.

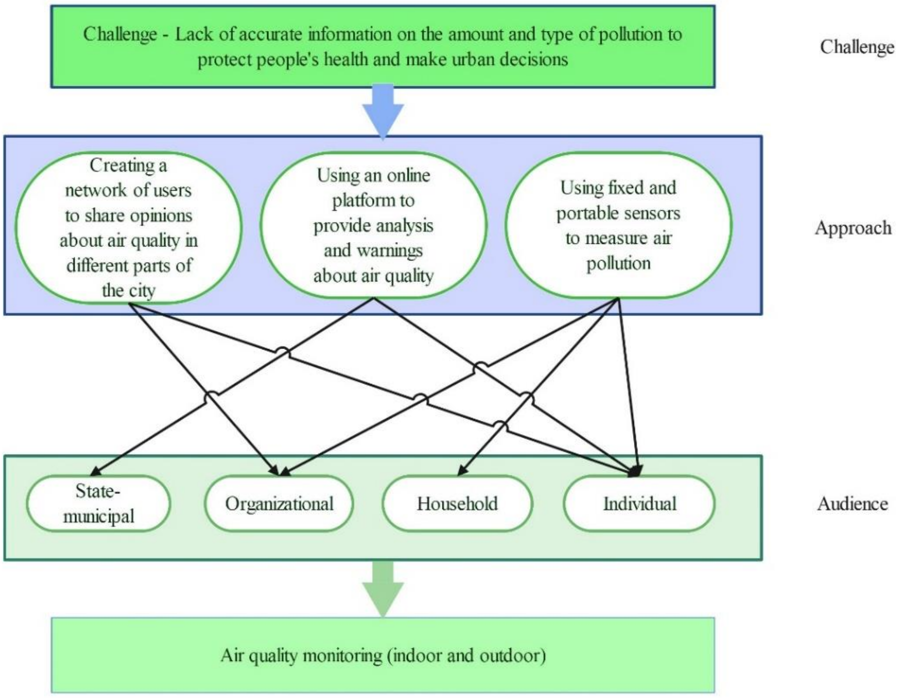

Fig. 6. Air pollution forecasting solutions.

CONCLUSION

Air pollution is a significant health crisis affecting both developed and developing countries, with various immunological and epidemiological effects on human health. This research presents a framework for air pollution monitoring, estimation, and control in smart cities of developing countries, based on expert agreement with available human resources in Tehran, Iran. The platform computes air pollution features with machine learning computations, and the AQI parameter is calculated. Standardization by strategy building is necessary for the DSS operation, and spatial and time series analysis should determine high-risk zones. After implementation, citizen feedback should evaluate DSS performance.

Future research could apply the classical Delphi model to increase agreement among experts with various expertise. High-risk air pollution effects, such as cancer evaluation, may be attractive to scientific communities.

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CONFLICT OF INTERESTS

The authors confirm that there is no conflict of interests associated with this publication.

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