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**Application of ubiquitous public  
access to-geographic information to  
an air quality information service**

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

Rapid urbanization and industrialization have led to a severe deterioration in the atmospheric environments of major cities<sup>[1][2]</sup>. Air pollutants, which include both naturally occurring and anthropogenic substances, are associated with illness and mortality in humans, and with damage to natural and built environments<sup>[3]</sup>. However, despite the dedicated actions over the past decades of both international and national organizations to decrease major pollutant emissions, urban air quality continues to worsen, affecting residential environments and harming the health of citizens<sup>[4]</sup>.

Information communication technology (ICT) has contributed to addressing the challenges of improving urban air quality. Sensor networks provide a powerful tool for monitoring air quality in real-time through widely dispersed monitoring stations<sup>[5][6]</sup>. Portable air pollution sensors, combined with the Global Navigation Satellite System (GNSS) technology, supplement an existing sensor network with enhanced availability and accessibility for monitoring air quality in near real-time<sup>[7][8]</sup>. Also, spatial data infrastructure (SDI) is established for integrated and interoperable management of air pollutant measurements at national and international levels. For example, INSPIRE, which is the European SDI based upon ISO 19156, defines a framework to access, share, and use air quality data from member countries<sup>[9]</sup>. The air quality information platform is a bridge between the sensor systems and the citizens. Both web- and mobile-based applications, highly coupled to geographic information systems (GIS), enable citizens to easily obtain air quality information services without spatial or temporal limitations.

As public awareness of urban atmospheric problems has risen, air pollution now has become both an environmental and social problem. Citizens are also encouraged to participate in air quality assessment and environmental governance<sup>[10]</sup>. These societal and technical changes require a new paradigm to develop an air quality information system and their services. Different from conventional air quality information systems, citizens are no longer only consumers of air quality information, but rather producers of air quality information. For example, a social media service such as a blog, Twitter, and Facebook are now major communication channels for expressing the concern of citizens about urban air quality issues. Social media technology platforms are now regarded as "social sensors" collecting citizens' perceptions of air quality<sup>[11][12]</sup>.

In this document, an air quality information system was developed, referencing ISO 19154. The ubiquitous public access to geographic information (UPA-to-GI) is a geographic information service for the general public to easily access and produce geographic data or information in a ubiquitous computing environment. In this system, the UPA context information model defined in ISO 19154 is employed to systematically associate air quality data from various information sources (e.g. physical sensor measurements, subjective citizen's opinions, and semantic social media data). The UPA context information model is also used to formulate air quality information services, conforming to the citizen's contextual requests.

This document aims to assist the understating of the UPA context information model and to illustrate its application for air quality information services. In this regard, a proof of concept (POC) study was conducted in Seoul, South Korea. The GIS-based air quality information system was designed and implemented to realize a UPA-based air quality information service. Globally, there are widely different approaches to monitor and report air quality. The UPA-based air quality information service model, described in this document, is a sample of all possible examples. However, the underlying idea and concept for designing and implementing the UPA context information model is still helpful to develop other UPA-based air quality information services, conforming to the unique atmospheric and social environments in each nation.

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# Application of ubiquitous public access to-geographic information to an air quality information service

## 1 Scope

This document facilitates an understanding of the Ubiquitous Public Access (UPA) context information model, as defined in ISO 19154, to establish a UPA-to-Geographic Information (GI) environment. In addition, this document illustrates how the UPA context information model is designed and implemented to provide an air quality information service from a geographic information system (GIS)-based air quality information system. The UPA context information model for air quality information is only a sample of all possible examples to realize the UPA-to-GI that could satisfy the requirements of ISO 19154.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

### 3.1

#### **air pollutant**

material emitted into the atmosphere either by human activity or natural processes and adversely affecting humans or the environment

[SOURCE: ISO 18158:2016, 2.1.2.1]

### 3.2

#### **application**

manipulation and processing of data in support of user requirements

[SOURCE: ISO 19101-1, 4.1.1]

### 3.3

#### **context**

aspects or properties of an entity that affect the behaviour or expectations of that entity in any given situation

[SOURCE: ISO 19154:2014, 4.4]

### 3.4

#### **comprehensive air-quality index**

##### **CAI**

description of the ambient air qualities based on the health risk of air pollution

EXAMPLE The higher CAI values, the greater the level of air pollution.

Note 1 to entry: The index aims to make the public easily understand how polluted overall air quality currently is or how polluted it is forecast to become.

**3.5**  
**geographic context awareness**  
*application* (3.2) or *service* (3.12) behaviour based on the recognition of user's *geographic context* (3.3)

[SOURCE: ISO 19154:2014, 4.7]

**3.6**  
**geographic information**  
information concerning phenomena implicitly or explicitly associated with a location relative to the Earth

[SOURCE: ISO 19101-1, 4.1.18]

**3.7**  
**geographic information service**  
*service* (3.12) that transforms, manages, or presents geographic information to users

[SOURCE: ISO 19101-1, 4.1.19]

**3.8**  
**geographic information system**  
**GIS**  
information system dealing with information concerning phenomena associated with location relative to the Earth

[SOURCE: ISO 19101-1, 4.1.20]

**3.9**  
**interface**  
named set of *operations* (3.10) that characterize the behaviour of an entity

[SOURCE: ISO 19119:2016, 4.1.8, modified — Note 1 to entry was deleted.]

**3.10**  
**operation**  
specification of a transformation or query that an object may be called to execute

[SOURCE: ISO 19119:2016, 4.1.10, modified — Notes 1 and 2 to entry were deleted.]

**3.11**  
**public access**  
open access to information sources and/or *services* (3.12) by general public users and professional users alike

[SOURCE: ISO 19154:2014, 4.18]

**3.12**  
**service**  
distinct part of the functionality that is provided by an entity through *interfaces* (3.9)

[SOURCE: ISO 19119:2016, 4.1.12]

**3.13**  
**ubiquitous public access**  
**UPA**  
*service* (3.12) that enables end-users to have easy and interoperable access to specific types of data, irrespective of their location or access device, and that match their interest criteria

EXAMPLE Linked Geodata Service.

Note 1 to entry: In the example, the Linked GeoData Service is responsible for openly inter-connecting geographic information to external repositories or web resources using a transform to either Resource Description Framework (RDF) or Web Ontology Language (OWL) format.

[SOURCE: ISO 19154:2014, 4.25]

## 4 Abbreviated terms and symbols

AQI	Air Quality Index
AQMA	Air Quality Mobile Application
AQODP	Air Quality Open Data Platform
AQSDP	Air Quality Social Media Data Platform
CAI	Comprehensive Air Quality Index
CO	Carbon Monoxide
CO <sub>2</sub>	Carbon Dioxide
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
ICT	Information Communication Technology
NO <sub>2</sub>	Nitrogen Dioxide
O <sub>3</sub>	Ozone
PM	Particle Matter
SDI	Spatial Data Infrastructure
SO <sub>2</sub>	Sulphur Dioxide
UPA	Ubiquitous Public Access
UPA-to-GI	Ubiquitous Public Access to Geographic Information
WFS	Web Feature Service
WMS	Web Map Service

## 5 UPA-to-GI environment for air quality information

### 5.1 Overview

ISO 19154 is a relatively new International Standard from ISO/TC 211, *Geographic information/ Geomatics*, that defines the reference architecture to realize UPA-to-GI environments. The UPA-to-GI environment aims to enable the general user to have easy and seamless access to geographic data and services regardless of their locations and computing devices. Also, the user is no longer just a recipient of geographic information, but also a producer of geographic information. To realize the UPA-to-GI environment, the UPA context information model, which is defined in ISO 19154, gathers and manages geographic context information from varied data sources including the user. Within the interactions between each user and an information system, the context information model is used to characterize a user's situation in relation with geographic information. Thus, the user can access information meeting

their needs in a convenient and interoperable manner. In this document, the high-level design of an air quality information system for the user to easily access air quality in real-time, and to contribute to air quality monitoring data for participating in societal environmental decision making is presented.

## 5.2 Main components

The air quality information system is built using UPA-to-GI concepts, as shown in [Figure 1](#) and is composed of three fundamental main components:

- a) air quality observation system ([5.2.1](#)),
- b) air quality information platform ([5.2.2](#)), and
- c) users ([5.2.3](#))

### 5.2.1 Air quality observation system

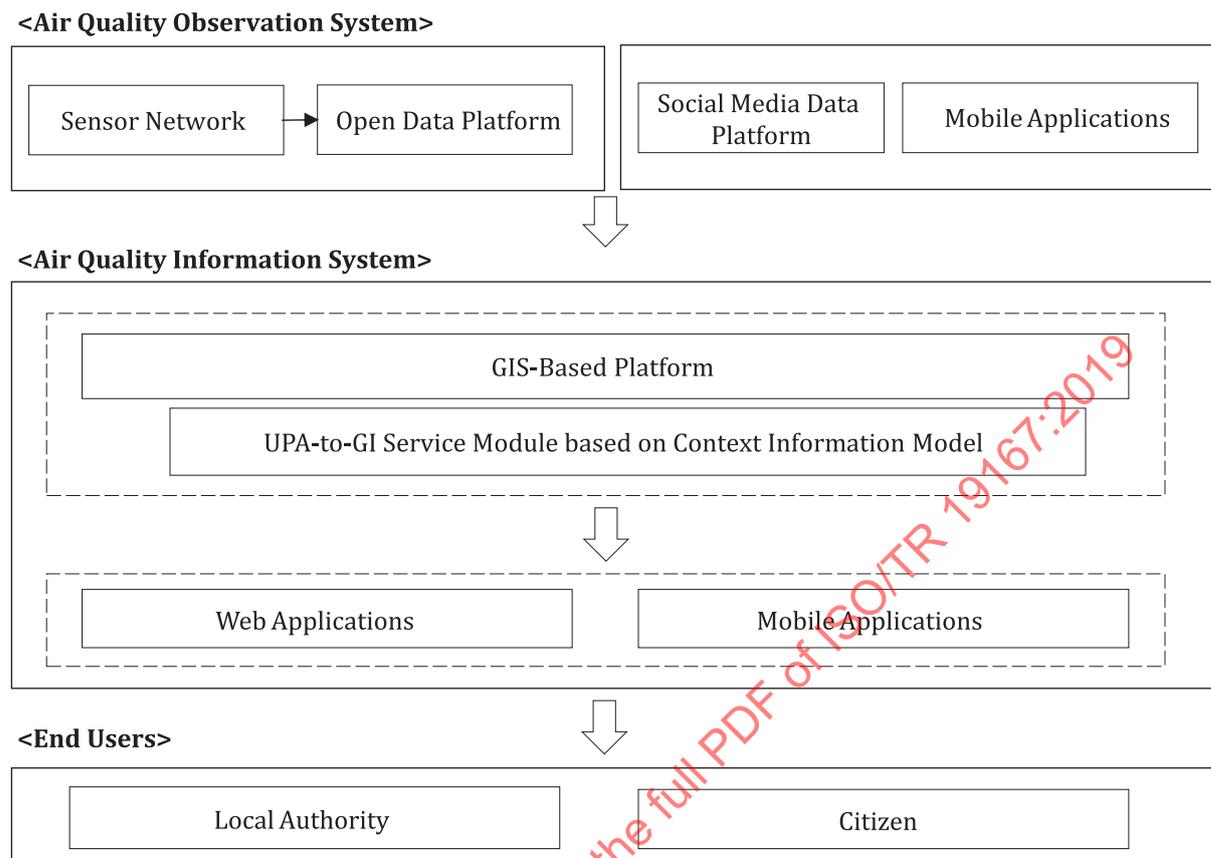
The application of ICT to a variety of air quality observation systems has contributed to resolving global air quality challenges. Air quality monitoring stations, connected in sensor networks, directly monitor air pollutants (PM, O<sub>3</sub>, NO<sub>2</sub>, CO and SO<sub>2</sub>) and obtain real-time data from widely dispersed locations. The Air Quality Open Data Platform (AQODP) stores and checks the quality of the data from the monitoring stations. The Air Quality Social Media Data Platform (AQSDP) is another channel to detect air quality issues from events occurring in real-time and reported within social media. The social media data, which social media users share with the public, describes any events or news that influence urban air quality such as a building fire or factory explosion. Furthermore, as public awareness of urban environmental problems has increased, Air Quality Mobile Application (AQMA) running on mobile devices can provide a mechanism for citizens to express their concerns about local air quality issues. The perceptions from the citizens, when combined with air quality data from air quality monitoring stations, will better enable local authorities to shape policies for improving urban air quality.

### 5.2.2 Air quality information system

In the UPA-to-GI environment, the air quality information platform is a bridge between heterogeneous air quality observation systems and end users. Air quality data from the observation systems are transmitted to the data hub of the platform, where the context information model employs geographic information to define how air quality data are structured and maintained. At the same time, the air quality information is explicitly or implicitly associated with user's contexts. The air quality information services, which consist of air quality information and action tips, are then created according to the user's location, time, and health status. The air quality platform is a basis for developing both web and mobile applications that enable users to easily access air quality information services irrespective of their locations or devices. These applications also allow users to produce air quality data based on their perceptions and opinions, which are submitted to the air quality information platform, as contributed social data.

### 5.2.3 Users

The main users of the air quality information system are citizens or local authorities. Local authorities will use the air quality information services for policy or operational decision making. For example, the air quality information platform provides locational air quality statistics along with citizens' perceptions of air quality. These data provide a reference by which to recognize knowledge and communication gaps between the citizens and policy makers. The web and mobile applications also convey air quality information services to citizens, allowing them to represent their opinions visually through an easy to understand graphic interface with icons and colours. Citizens can use the services when planning outdoor activities and decisions on where to live or relocate.



**Figure 1 — Main components in UPA-GI based air quality information**

### 5.3 Air quality index

In the UPA-to-GI environment for air quality information, the air quality information platform collects air quality data from the air quality observation systems. The air quality contexts are then extracted and associated with contexts from users to provide relevant air quality information services. The air pollutant measures obtained from the air quality monitoring station are simply numerical data, therefore they are converted into a region-appropriate Air Quality Index (AQI) scheme to help citizens more easily understand air quality levels and to protect their health during episodes of severe air pollution. AQI indicates an overall air quality derived from all air pollutant measurements, as shown in [Table 1](#). The health implications corresponding to index categories are shown in [Table 2](#).

Different countries employ specific air quality indices, corresponding to their respective national air quality standards. This document presents examples using the Comprehensive Air Quality Index (CAI) and behavioural guidelines established for use in the Republic of Korea<sup>[13]</sup>.

**Table 1 — Comprehensive air-quality index (CAI)**

Pollutant	Good	Moderate	Unhealthy	Very Unhealthy	
				I	II
CAI	0~50	51~100	101~250	251~350	351~500
PM <sub>2.5</sub> (µg/m <sup>3</sup> )	0~15	16~50	51~100	101~250	251~500
PM <sub>10</sub> (µg/m <sup>3</sup> )	0~30	31~80	81~150	151~300	301~600
O <sub>3</sub> (ppm)	0~0,030	0,031~0,090	0,091~0,150	0,151~0,500	0,501~0,600
NO <sub>2</sub> (ppm)	0~0,030	0,031~0,060	0,061~0,200	0,201~0,600	0,601~2,000
CO (ppm)	0~2,000	2,001~9,000	9,001~15,000	15,001~30,000	30,000~50,000

**Table 1 (continued)**

Pollutant	Good	Moderate	Unhealthy	Very Unhealthy	
				I	II
SO <sub>2</sub> (ppm)	0~0,020	0,021~0,050	0,051~0,151	0,151~0,400	0,401~1,000

**Table 2 — Health implications**

Index	Description
Good	A level that will not impact patients suffering from diseases related to air pollution.
Moderate	A level that may have a minor effect on patients in case of chronic exposure.
Unhealthy	A level that may have harmful impacts on patients and members of sensitive groups (children, elderly, or infirm people), and may cause unpleasant feelings among the general population.
Very Unhealthy I	A level that may have serious impacts on patients and members of sensitive groups in case of acute exposure.
Very Unhealthy II	A level that may require emergency measures for patients and members of sensitive groups, and may have harmful impacts on the general population.

**5.4 Use case diagram**

The following use cases depicted in [Figure 2](#) consist of a series of actions defining the interactions between the main stakeholders, either citizens or local authorities. The citizens are further categorized based on their potential health risk due to air quality, such as a sensitive or high-risk group such as the young and elderly people, or citizens with respiratory or cardiovascular issues. The context information, which is required for all users, consists of age, health status, geographical regions of interest, and current location. This information is transmitted to the air quality information platform through the “Register User Information” case. The user is then categorized as part of the “General Group” or “Sensitive Group,” based on analysis of their context information.

The air quality observation system includes AQODP and AQSDP. Additionally, the “Input Citizen Opinion” case in AQMA delivers a citizen's perceptions of air quality relevant to their current location, and can present their concerns about the air quality using a categorized icon. The “Show Citizens Opinion” case employs an urban map to spatially represent the perceptual concerns registered by the citizens, regarding local air quality issues. Local authorities can use the knowledge and perceptive experience submitted directly from the citizens when establishing new air quality policies.

In AQMA, the “Receive Location-based Real-Time Air Quality Information” case provides estimated air quality information for a user's current location when the GNSS on a mobile device is activated. The “Receive Regional Air Quality Information of Interest” case retrieves regional air quality when users register a geographical region of interest. The “Receive Forecast of Air Quality Information” retrieves an air quality forecast for the following day. The use case of “Receive Warning Message and Action Tip” issues warning messages and action tips, considering the user's contexts from the “Register User Information” case. The warning message is issued when AQI exceeds the level of health concern or when a user's location is near an air quality event. The action tip is a behavioural guideline to propose what actions the citizens should take to protect their health against each air pollutant incident.

The “Receive Regional Air Quality Statistics” case involves current and past air quality data from AQODP, and computes daily, monthly, and yearly averages for each region of a city. Citizens can refer to these statistics when deciding on where to relocate or reside for long-term health recovery purposes, whereas policy makers can use such data to judge the effectiveness of the existing air quality policies.

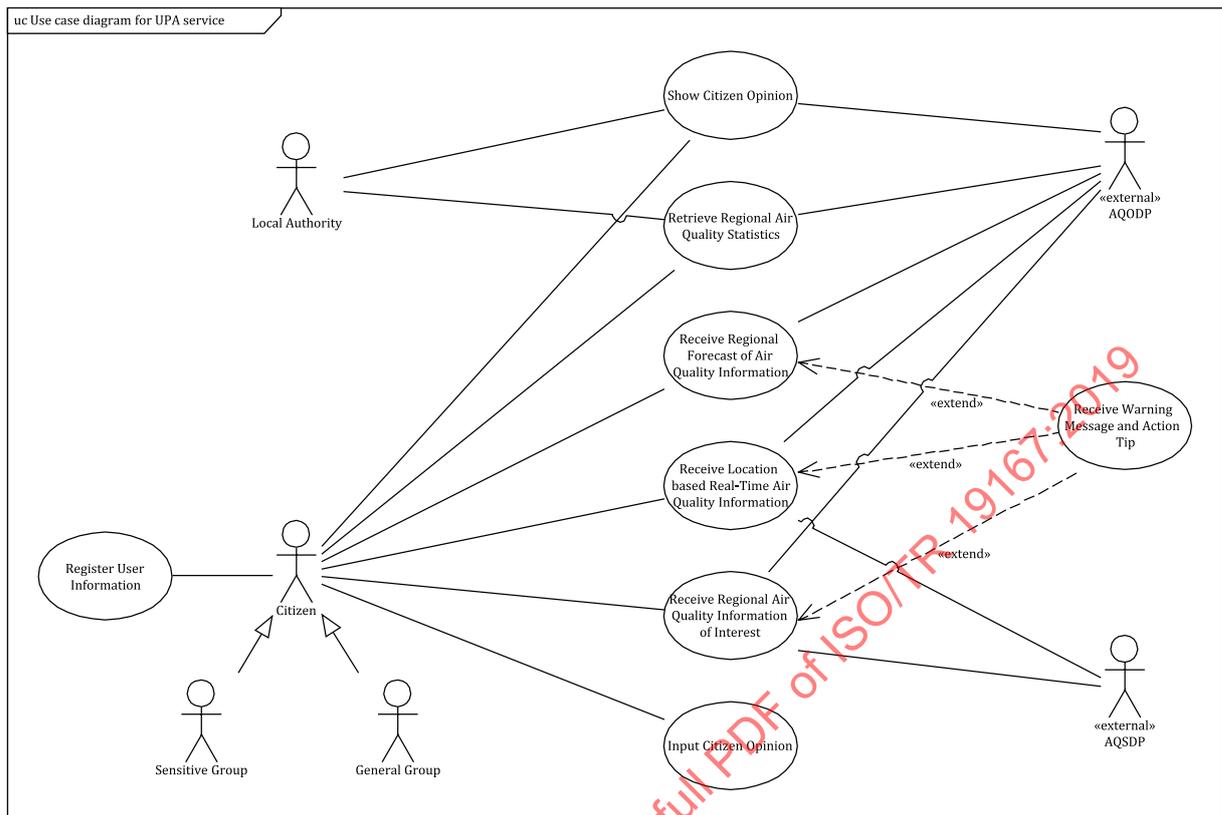


Figure 2 — Use case diagram for UPA service

## 6 UPA context information model in ISO 19154

### 6.1 Overview

In ISO 19154, the UPA context information model is conceptually specified for an information system to support the UPA-to-GI. The UPA context information model is based upon seamless mobility and geographic context. The geographic context, which is the entity's contexts in relation to geographic information, includes an entity's location, speed, and orientation, and other relevant static location data such as nearby restaurants and hospitals or dynamic data such as traffic and weather conditions. The geographic context enables an information system to provide a set of tailored geographic information artefacts, satisfying an entity's contextual requirements. However, as geographic information can be represented in various forms, the UPA context information model, as shown in [Figure 3](#), defines three different context levels of geographic information:

- UPA locational ([6.2](#)),
- UPA geospatial ([6.3](#)), and
- UPA geosemantic contexts ([6.4](#)).

### 6.2 UPA location context package

The UPA locational context package identifies types of location that are representative of an entity (e.g. vehicle's geographic coordinate measure from GNSS) and defines rules for extracting relevant contexts from the location information of the entity (e.g. vehicle's speed and orientation).

### 6.3 UPA geospatial context package

In the UPA geospatial context package, the locational entity is allocated the geospatial representation type inferred by its locational contexts (e.g. a vehicle represented as a point feature on a roadway map). The geospatial rule is used to retrieve relevant contexts from the entity’s geospatial information (e.g. shortest route and travel distance computed along with a roadway map).

### 6.4 UPA geosemantic context package

The geosemantic context package, which is inherited from the location context package, employs the geospatial entity to explicitly represent the implicit expression of the locational context of the entity. The geosemantic type and a set of rules are used for geographical extraction and inference of relevant context from the locational contexts of the entity (e.g. a location of vehicle’s accident inferred from news).

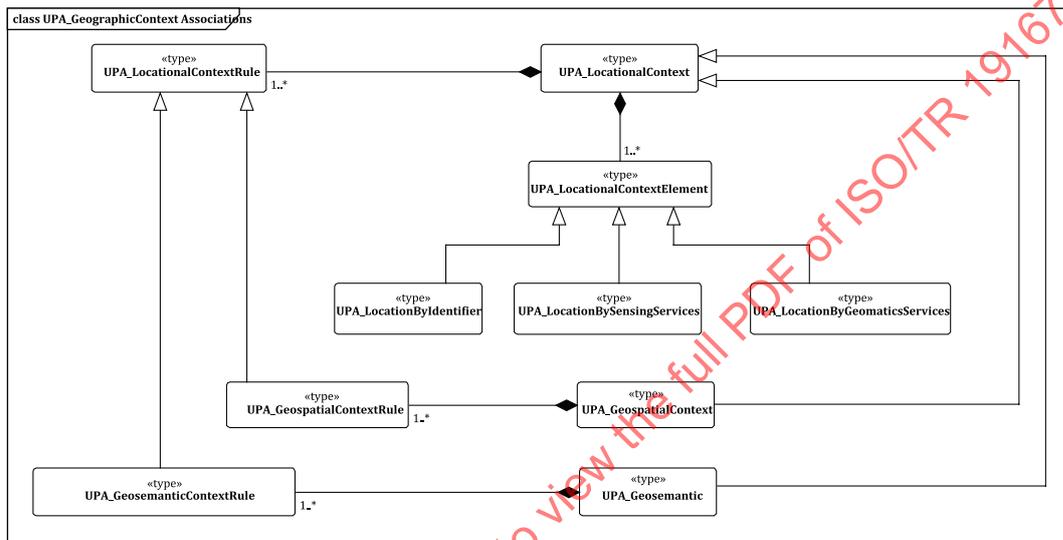


Figure 3 — Geographic context information model in ISO 19154

## 7 Air quality context information model

### 7.1 Overview

In this document, the air quality context information model refers to the UPA context information model from ISO 19154, as shown in Figure 4. The air quality context information model, as shown in Figure 5, primarily involves air quality data from the air quality observation systems that consists of the AQODP, AQSDP, and AQMA. In particular, AQMA running on a smart phone is utilized for users to access an air quality information as well as to provide their perceptions of air quality as social data.

In the UPA-to-GI service module, the air quality context information model is used to structure and maintain air quality information from the air quality observation systems. The air quality context information model is further categorized into locational, geospatial, and geosemantic context information models. In Figure 5, the geographic context awareness is a function of the recognition of a user’s contexts in relation to the air quality information, from which spatially relevant air quality information services can be formulated, depending on the user’s locations, time, and health conditions. The air quality information service includes real-time air quality information, the air quality forecasts, air quality statistics, warning messages, action tips, and citizens’ opinions on air quality.

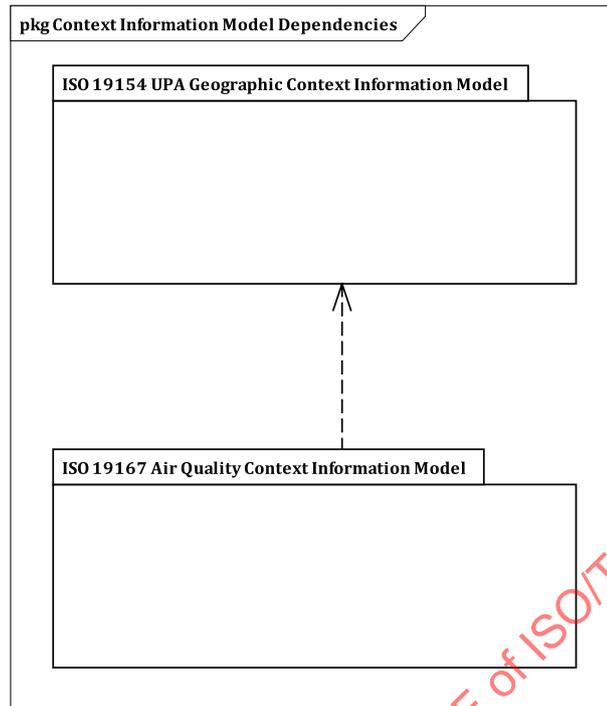


Figure 4 — Dependency of air quality context information model on UPA geographic context information model in ISO 19154

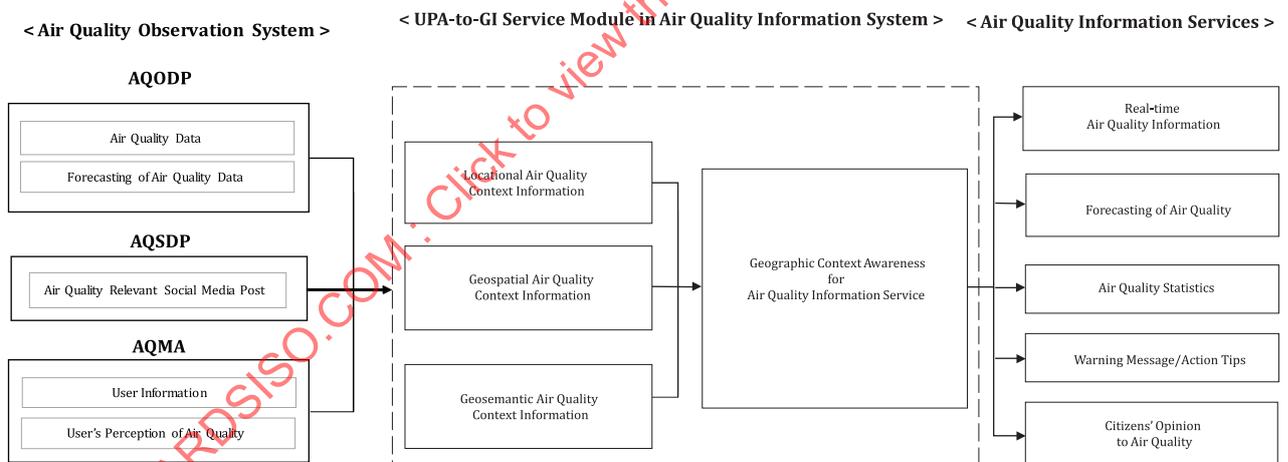


Figure 5 — Information flow for UPA-to-GI based air quality information services

## 7.2 Locational air quality context information model

The locational air quality context information model as shown in Figure 6 is a set of classes inferred from the UPA\_LocationContext class (Figure 3). The air quality context classes are designed for the users who use AQMA, the air quality monitoring stations that provide air quality data to AQODP, and the air quality event detected from AQSDP (Tables 3, 4, and 5). These classes are associated to retrieve and infer locational contexts from users, air quality monitoring stations, and air quality events (Table 6).

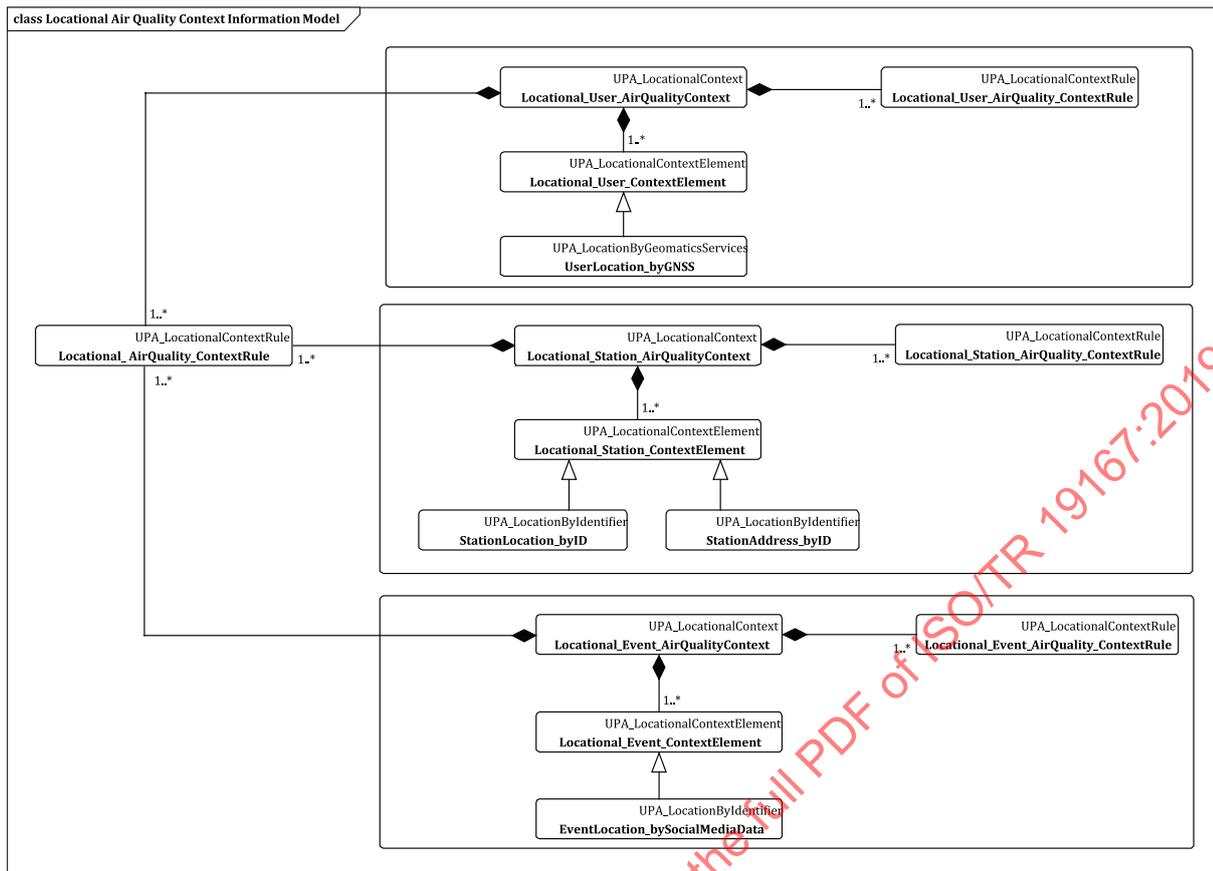


Figure 6 — Locational air quality context information model

AQMA requires all users to register information such as their age and health status, along with specific regions of interest. Based on the registered information, the users are categorized as belonging to the general group or a sensitive group (e.g. the young, elderly, and those with respiratory/cardiovascular issues), based on their age and health status. The GNSS on a mobile device provides a means to identify users' locations. The set of classes, which describes users' locational air quality context, is shown in Table 3 and within the solid line in Figure 6.

Table 3 — Locational air quality context classes for users

Class name	General description
Locational_User_AirQualityContext	Defines user contexts according to age, health status (e.g. the young, elderly, and those with respiratory/cardiovascular issues), and region of interest (e.g. home and company addresses).
Locational_User_AirQuality_ContextRule	Determines a user type (general or sensitive group) according to the user's information (e.g. age and health status).
Locational_User_ContextElement,	Defines a way of retrieving a user's location.
UserLocation_byGNSS	Contains the geographic coordinates of the user's current location, obtained via GNSS directly from a mobile device.

The relevant locational and air quality contexts of an air quality monitoring station can be retrieved from AQODP. A unique identity (ID) assigned to each air quality monitoring station is fundamental to collecting locational information (geographic coordinates and address), real-time air quality data (PM, CO, O<sub>3</sub>, NO<sub>2</sub>, and SO<sub>2</sub>), and air quality forecasts. In addition, the air quality statistics allow comprehensive analyses of air qualities at the air quality monitoring station. The set of classes, which describes the locational air quality contexts of an air quality monitoring station, are shown in Table 4 and within the dotted line in Figure 6.

**Table 4 — Locational air quality context classes for air quality monitoring station**

Class name	General description
Locational_Station_AirQualityContext	Defines contexts of an air quality monitoring station with ID, station name, past and real-time air quality data (PM, CO, O <sub>3</sub> , NO <sub>2</sub> , and SO <sub>2</sub> ), and air quality forecasts. This information is retrieved from AQODP.
Locational_Station_AirQuality_ContextRule	Computes the air quality statistics.
Locational_Station_ContextElement,	Defines a way of retrieving a station's location.
StationLocation_byID	Contains the geographic coordinates of the air quality monitoring station. The station ID is used to retrieve its geographic coordinates from AQODP.
StationAddress_byID	Contains the address of the air quality monitoring station. The station ID is used to retrieve its address from AQODP.

Social media data, which are transmitted from AQSDP, is used to contain implicit information regarding air quality events (e.g. a forest wildfire on South Mountain, Seoul). Thus the air pollutants, which vary in response to air quality events, are then inferred. For example, a forest wildfire can be a source of increased PM and CO pollution around the event location. The set of classes, which describes the locational contexts of air quality events, is shown in [Table 5](#) and within the dashed line in [Figure 6](#).

**Table 5 — Locational air quality context classes for air quality events**

Class name	General description
Locational_Event_AirQualityContext	Utilizes AQSDP to define the contexts of an air quality event (ID, date and time, and the location and type of air quality event).
Locational_Event_AirQuality_ContextRule	Infers which air pollutants might be influenced, based on the type of air quality event.
Locational_Event_ContextElement	Defines a way of retrieving the air quality event location from the social media data.
EventLocation_bySocialMediaData	Contains an implicit expression of the air quality event location.

The locational air quality context is inferred by associating locational air quality contexts from users, air quality monitoring stations, and air quality events. The inference rule identifies the air quality monitoring station within the user's region of interest, subsequently retrieving real-time (or forecasted) air quality information for that region. The `Locational_AirQuality_ContextRule` class, described in [Table 6](#), is shown in [Figure 6](#).

**Table 6 — Locational air quality context classes for user, air quality monitoring station, and air quality event**

Class name	General description
Locational_AirQuality_ContextRule	Associates contexts from user, air quality monitoring station, and air quality event, and infers comprehensive air quality contexts (e.g. air quality information and statistics from the user's region of interest).

### 7.3 Geospatial air quality context information model

The geospatial air quality context information model in [Figure 7](#), which is a set of classes inferred from the type `UPA_GeospatialContext` in [Figure 3](#), refers to the geospatial context classes for a user and an air quality monitoring station ([Tables 7](#) and [8](#)). These are associated to retrieve and infer geospatial contexts from the user and the air quality monitoring station ([Table 9](#)).

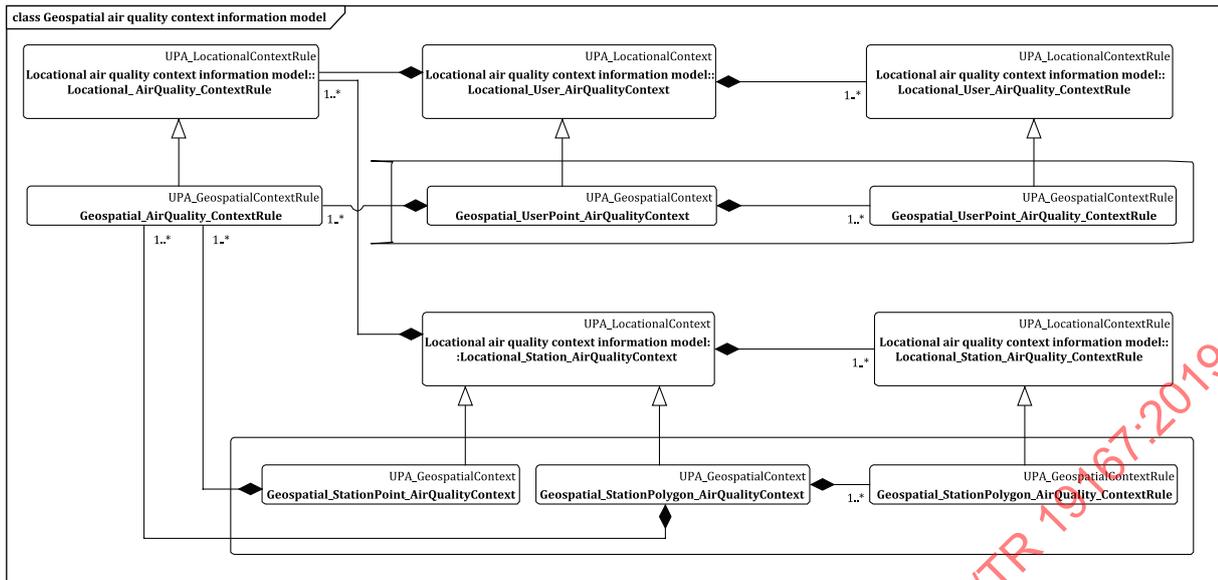


Figure 7 — Geospatial air quality context information model

A user’s geospatial context is represented as a point feature in the air quality information system. The user’s current address is determined using appropriate geocoding methods, enabling a user to rate the air quality at their current locations. The rating submitted by the user is reformatted and added to the air quality information system to subjectively represent how the user feels about the air qualities in comparison with the air quality data from the monitoring station. The set of classes, which describes the geospatial contexts of a user, is shown in Table 7 and within the dotted line in Figure 7.

Table 7 — Geospatial air quality context classes for users

Class name	General description
Geospatial_UserPoint_AirQualityContext	Represents the user as a point feature, as inferred from the locational air quality context information model. The user’s opinion on air quality at their current location becomes the user’s context.
Geospatial_UserPoint_AirQuality_ContextRule	Defines a rule for inferring geospatial air quality contexts. The rule defines the geocoding method to obtain a user’s address at the current location, and the buffering method to retrieve the locations of nearby hospitals.

The geospatial contexts of the air quality monitoring station are represented as point and polygon features in the air quality information system. In this document, an air quality monitoring station is installed in each region of the city. As air quality data from each station are representative of each region, the air quality data are coded to a polygon feature that depicts the administrative boundary of the region. The set of classes, which describes the geospatial contexts of an air quality monitoring station, is shown in Table 8 and within the dashed line in Figure 7.

Table 8 — Geospatial air quality context classes for air quality monitoring stations

Class name	General description
Geospatial_StationPoint_AirQualityContext	Represents the air quality monitoring station as a point feature, as inferred from the locational air quality contexts for the air quality monitoring station.
Geospatial_StationPolygon_AirQualityContext	Represents the air quality monitoring station as a polygon feature, as inferred from the locational air quality contexts for the air quality monitoring station.

Table 8 (continued)

Class name	General description
Geospatial_StationPolygon_AirQuality_ContextRule	Defines a rule for inferring geospatial air quality contexts, which assigns air quality data to the polygon features.

The geospatial air quality contexts are inferred by retrieving and associating the geospatial contexts from the user and the air quality monitoring station. The air quality conditions at the user's current location can be established via geospatial operations that interpolate air quality values using data from nearby air quality monitoring stations. The Geospatial\_AirQuality\_ContextRule class is described in Table 9 and shown in Figure 7.

Table 9 — Geospatial air quality context classes for user and air quality monitoring station

Class name	General description
Geospatial_AirQuality_ContextRule	Defines a rule for inferring geospatial air quality contexts from a user's location and nearby air quality monitoring stations. The rule includes geospatial operations to identify and obtain air quality data from nearby air quality monitoring stations. Interpolation methods such as Kriging and Inverse Distance Weighting (IDW) are then applied to infer the air quality data at the user's current location.

### 7.4 Geosemantic air quality context information model

The geosemantic air quality context information model in Figure 8, which is a set of classes inferred from the type UPA\_GeosemanticContext in Figure 3, describes the geosemantic context classes of an air quality event detected from AQSDP (Table 10). The geosemantic air quality contexts are inferred by retrieving and associating the geosemantic contexts of the air quality event with a user's geospatial context (Table 11).

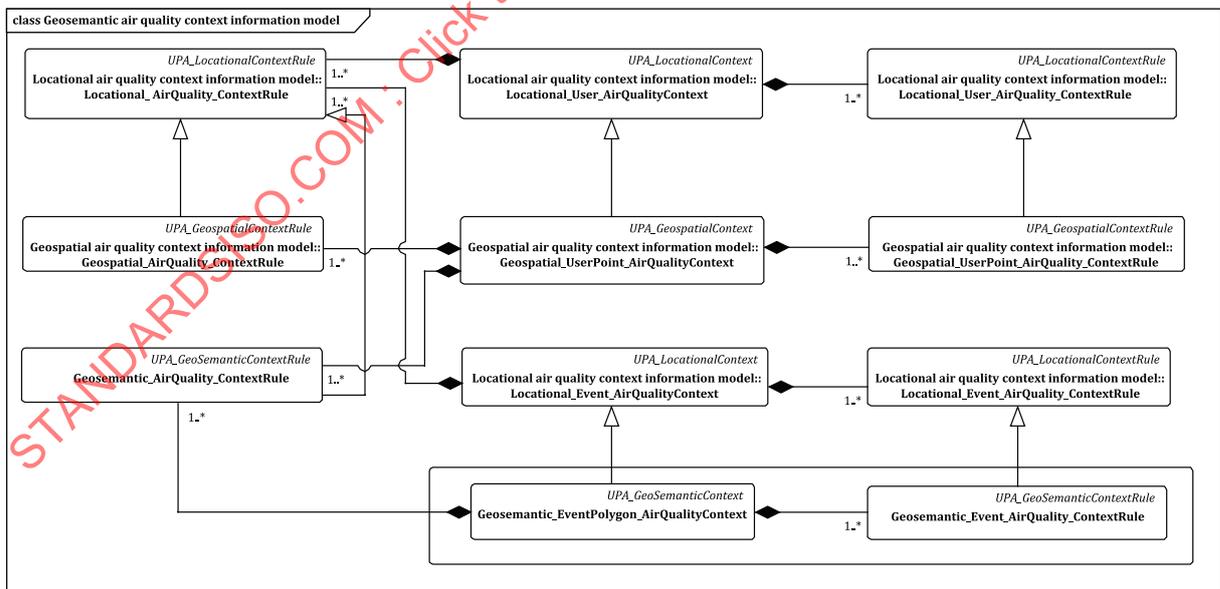


Figure 8 — Geosemantic air quality context information model

Within the air quality information system, the location of the air quality event, which is implicitly expressed in the social media data, is explicitly represented as a polygon feature. For example, if an air quality event implicitly refers to a fire event in “Dongdaemun-Gu” (a regional district in Seoul), a regional polygon of “Dongdaemun-Gu” would be used to indicate the possible location of the fire event. The polygon feature represents the area of a source of air pollution (potentially generating PM and CO,

etc.). Meanwhile, the zone affected by the air pollution is determined via the types of air pollutants inferred from the air quality event. The set of classes, which describes the geosemantic contexts of an air quality event, is shown in [Table 10](#) and within the dotted line in [Figure 8](#).

**Table 10 — Geosemantic air quality context classes for air quality events**

Class name	General description
Geosemantic_EventPolygon_AirQualityContext	Represents an air quality event as a polygon feature, as inferred from the locational context information model for the social media data.
Geosemantic_Event_AirQuality_ContextRule	Defines a rule for inferring geosemantic air quality contexts. The rule includes methods to determine the zone affected by air pollution from the air quality event.

The geosemantic air qualities are inferred by retrieving and associating the geosemantic contexts of an air quality event with a user's geospatial contexts. The geospatial operation is employed to retrieve and issue a warning message to users within the zone affected by an air quality event. The Geosemantic\_AirQuality\_ContextRule class, described in [Table 11](#), is shown in [Figure 8](#).

**Table 11 — Geosemantic air quality context class for association of user and air quality events**

Class name	General description
Geosemantic_AirQuality_ContextRule	Defines a rule for inferring air quality contexts from the geospatial contexts of a user and geosemantic contexts of an air quality event. The rule includes the geospatial operation method to retrieve users within the zone affected by the air quality event and issue a warning message to the affected users.

## 8 Implementation of the air quality context information model

### 8.1 Overview

Seoul, South Korea is home to more than 10 million citizens and over the past years, many of them have increased concerns about air quality problems. As part of a collaborative research project, which is entitled as "CITI-SENSE - Development of sensor-based citizens' observatory community for improving quality of life in cities" under EU FP7, an air quality information system was implemented for the city of Seoul as shown in ([Figure 9](#)). In the city, air quality data, collected from 25 monitoring stations, are transferred and stored in an open data platform.



Figure 9 — Test site (Seoul, South Korea)

## 8.2 Air quality information system components

The air quality information system, as shown in [Figure 10](#), was developed using open source software technology, and consists of three main components:

- a database,
- a server, and
- a client interface.

The database system is built using PostgreSQL and the Post-GIS geospatial data plug-in for PostgreSQL is used to save, retrieve, and analyse air quality data. The server, which was constructed based on Apache/Tomcat configuration, uses both Socket module and HTTP client module to collect air quality data from external platforms such as AQODP and AQSDP. In the system, air quality data are associated with geographic information. The GeoServer platform is employed to activate both a WMS (Web Map Service) and WFS (Web Feature Service). In addition, the Restlet framework is used to provide the air quality information smoothly for web/mobile client devices. To render the geographical representations of air quality information, the web clients use Openlayers while the mobile clients use Leaflet libraries. In this document, the mobile client, which was developed on Google Android, provides a robust platform to deploy the UPA-to-GI based air quality information service. In the next section, implementation results are fully described with sample examples of air quality information service.

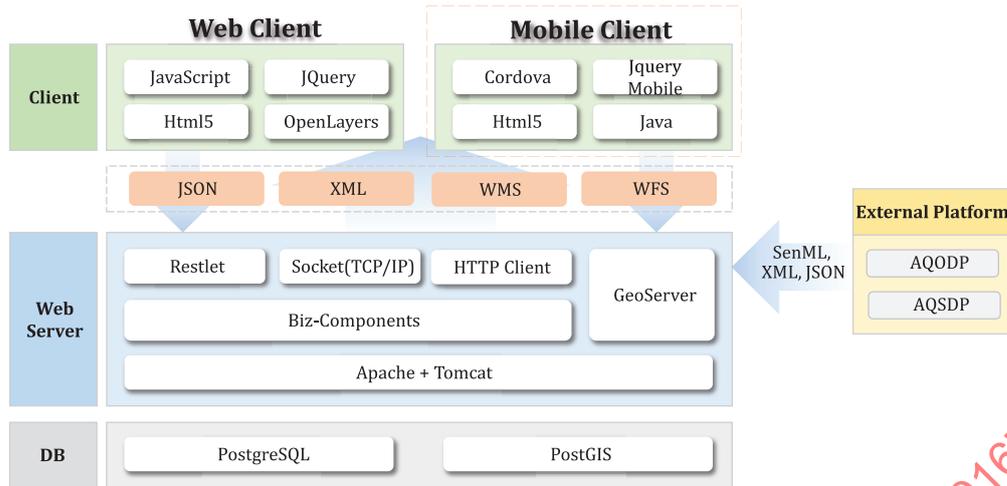
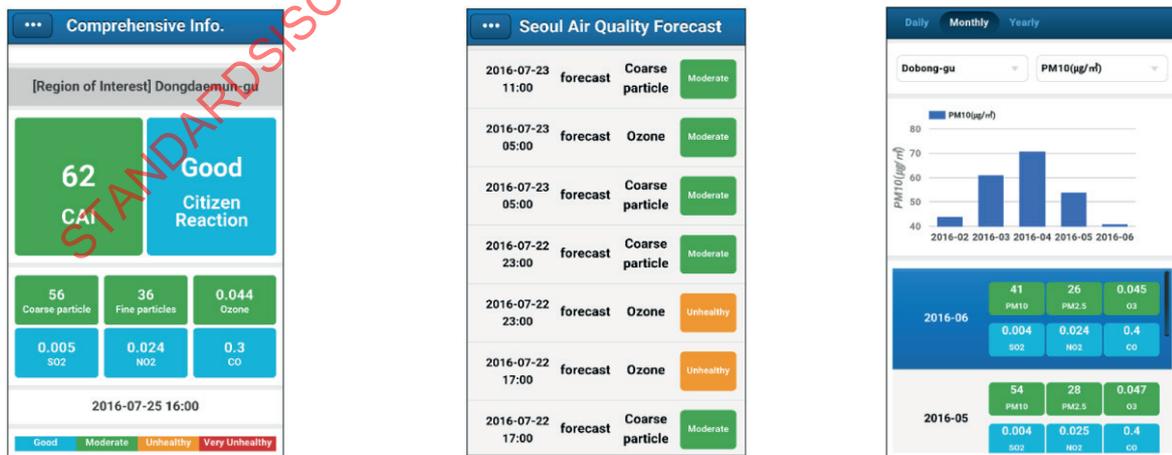


Figure 10 — Overall architecture of GIS based air quality information system

### 8.3 Air quality information service

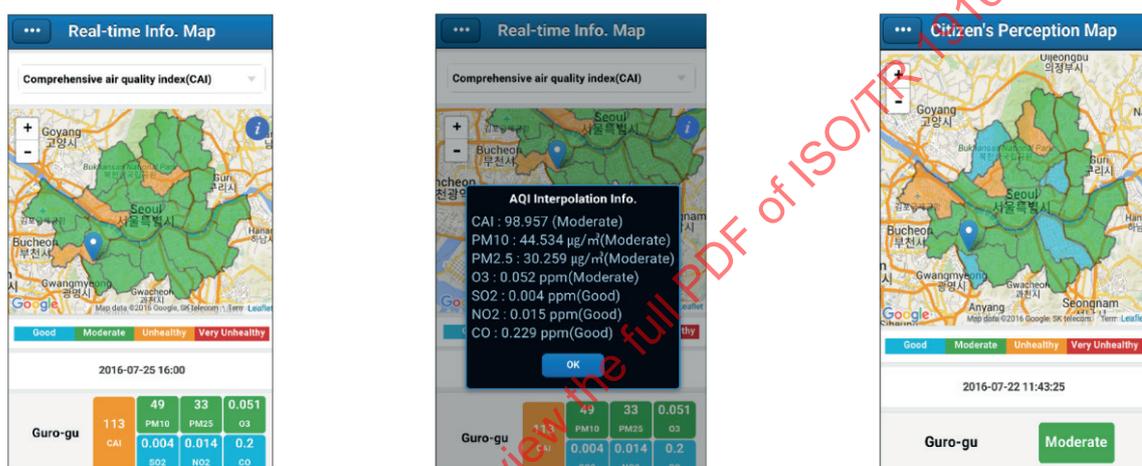
The air quality information service is developed according to the air quality context information model described in Clause 6, and thus it consists of locational, geospatial, and geosemantic air quality information services. The locational air quality information service is formulated based upon extracted or inferred locational contexts from the user and the air quality monitoring station. Figure 11 shows interface applications for locational air quality information services such as a real-time air quality information for regions of interest, an air quality forecast, and air quality statistics. The locational air quality information service is a function of associating locational air quality contexts from users and air quality monitoring stations. The user's locational contexts, which are registered in AQMA, includes multiple regions of interest. The locational contexts of an air quality monitoring station can be retrieved from AQODP. The unique ID, assigned for each air quality monitoring station, is used as a key to retrieve its address and to collect a real-time air quality information and air quality forecasts. The real-time (or forecasted) air quality information can be retrieved in accordance with a user's region of interest [Figure 11 (a) and (b)]. In addition, the air quality statistics provide a comprehensive view to spatially and temporally analyse the air quality at the location of the air quality monitoring station [Figure 11 (c)].



(a) Comprehensive air quality information in region of interest (b) Air quality statistics (PM10 in Dobong-gu, Seoul) (c) Air quality forecast

Figure 11 — Sample examples of locational air quality information

In the air quality information system, the geospatial air quality information is generally shown in conjunction with some type of background or base map, such as an urban map. The position of the user obtained from GNSS on the mobile device is encoded as a two-dimensional geographic coordinate pair and represented on the map using a point symbol. [Figure 12](#) shows application output examples of the geospatial air quality information service, comprising maps of a regional air quality, a location-based air quality, and a perceived air quality. In [Figure 12 \(a\)](#), the geospatial context of the air quality monitoring station is represented with the polygon feature. An air quality monitoring station is installed in each region of the city. As air quality data from each station is representative for each region, the air quality data is associated with the polygon feature that depicts a specific administrative area of the region. In [Figure 12 \(b\)](#), the air quality values at the user's current location are interpolated with air quality data from nearby air quality monitoring stations. In [Figure 12 \(c\)](#), the user's current address is computed using geocoding, enabling the users to rate the perception of air quality at their current regions. The user's rating is used as social data to subjectively represent how they feel about the air quality at their current region in comparison to the air quality data from the monitoring station.



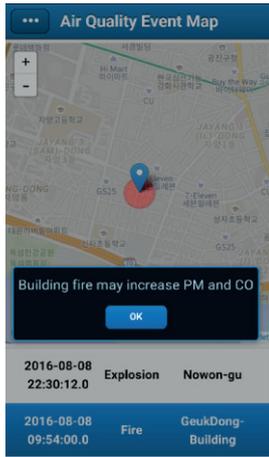
**(a) Regional air quality information**

**(b) Location-based air quality information**

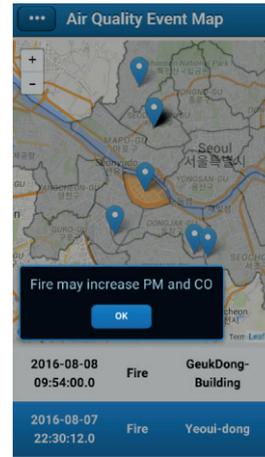
**(c) Citizens' perception map of air quality**

**Figure 12 — Sample examples of geospatial air quality information**

The geosemantic air quality information service includes the air quality event map and the warning message. The social media data, which is transmitted from AQSDP, contains implicit locational information of air quality events. Thus, the air quality information system employs the geospatial entities to explicitly represent air quality events overlaid on the urban map. Air pollutants, which are potentially influenced by the air quality event, can then be inferred. In [Figure 13 \(a\)](#), the buffer indicates an area that social media data refer to a fire in a building. In [Figure 13 \(b\)](#), the highlighted polygon indicates that the social media data refers to a fire somewhere in Yeoui-Dong, Seoul. The warning message is then shown to users currently located near the event, indicating that individuals sensitive to air pollution should exercise caution, as the fire might lead to high concentrations of CO and PM.



(a) Air quality event map with a buffer



(b) Air quality event map with a regional polygon

Figure 13 — Sample examples of geosemantic air quality information

## 9 Conclusions

The severe deterioration in urban atmospheric environments has become a major social issue as air quality maintains a close relationship with quality of life. Although large efforts have been made to improve urban air quality, it continues to worsen in many cities and is causing a harmful impact on citizens' health. However, ICT technological advances are opening new possibilities to encourage the participation of citizens in air quality assessment and environmental governance. In this regard, an air quality information system, based on the UPA-to-GI reference model specified in ISO 19154, was developed.

This system, which is highly coupled to a GIS, provides a means of raising the environmental awareness of citizens as well as promoting their participation in civic environmental decisions. The air quality context information model implemented in the system has a central role to collect, extract, and associate contextual air quality information from heterogeneous air quality observation systems. The air quality context information model is used to characterize contexts of users, air quality monitoring station, and air quality events in relation with geographic information. The air quality context information model is categorized as locational, geospatial, and geosemantic context information models. Therefore, different levels of a contextual relationship between users and air quality information can be defined, from which, more tailored air quality information services can be generated considering user's contextual requests. For validation and verification purposes, an air quality information system based on the air quality context information model was implemented for citizens of Seoul, South Korea. Implementation results showed that the air quality information system generated spatially relevant air quality information services, depending on the location and air quality situations near a specific user. The implemented system also allowed citizens to assess the air quality at their current locations or in regions of interest.

In this document, the design of the air quality context information model was primarily focused on realizing UPA-to-GI based air quality information services. ISO 19119 defines technical requirements to design geographic information services specific to GIS-based platforms. Thus, an additional standard to ISO 19119 is necessary to illustrate an entire lifecycle-based perspective of an air quality information service.

## Annex A (informative)

### Investigation of global air quality information

Air pollution has continued to worsen, despite dedicated international and national initiatives to improve air quality. The World Health Organization (WHO) reported that 92 % of the world's population is exposed to air pollutants beyond the WHO limit<sup>[13]</sup>. Air quality has already become one of the environmental risks to health, affecting the quality of citizens' lives. Recent advances in ICT have stimulated a shift of technical and societal paradigms to develop an air quality information system and its services. With the proliferation of wireless communication and mobile computing technologies, a portable device with GNSS technology (e.g. a smart phone and a tablet) enables citizens to easily access air quality information without spatial and temporal limitations. Citizens have also become providers of air quality information. In this Annex, air quality information from mobile applications are investigated and categorized in accordance with this document. Geospatial air quality information is still at an experimental level in universities and research institutes. Almost all air quality information available from public and commercialized air quality information systems belong to the locational or geospatial air quality information. As numerous applications are available globally, the following representative air quality information systems are selected for illustrative purposes.

In [Figure A.1](#), up-to-the-minute air quality data in a region of interest is shown with a descriptive index, symbol, and graph. The locational air quality information is limited to spatially analyse the air quality of multiple locations. This simple and straightforward design is effective for communicating air quality status to users. Also, air quality statistics are used for better understanding of a regional air quality history.

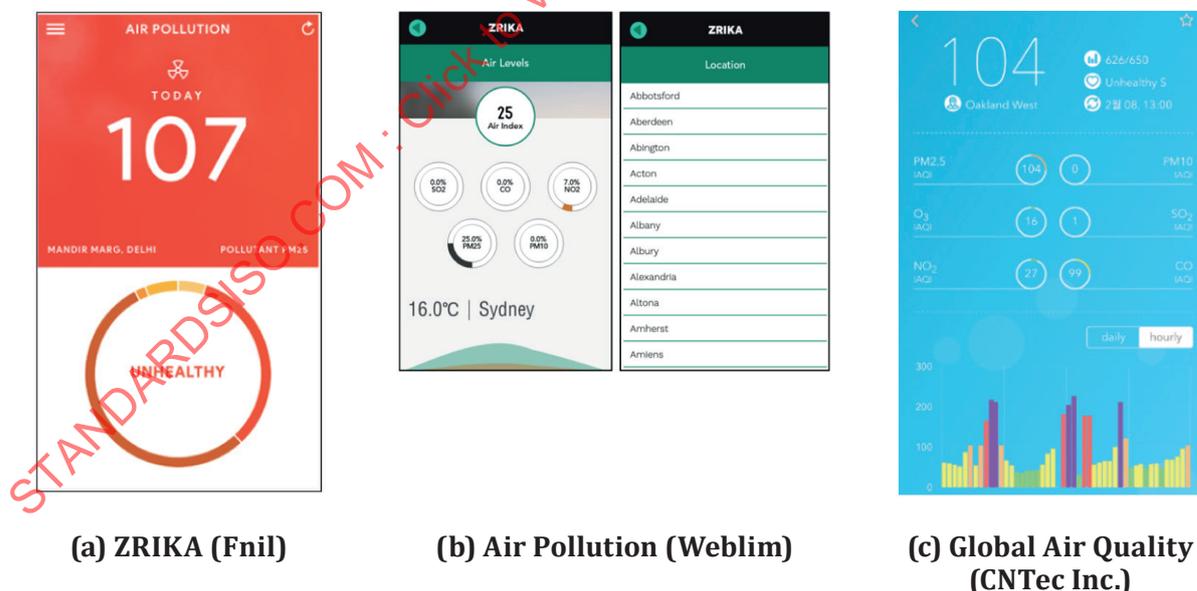
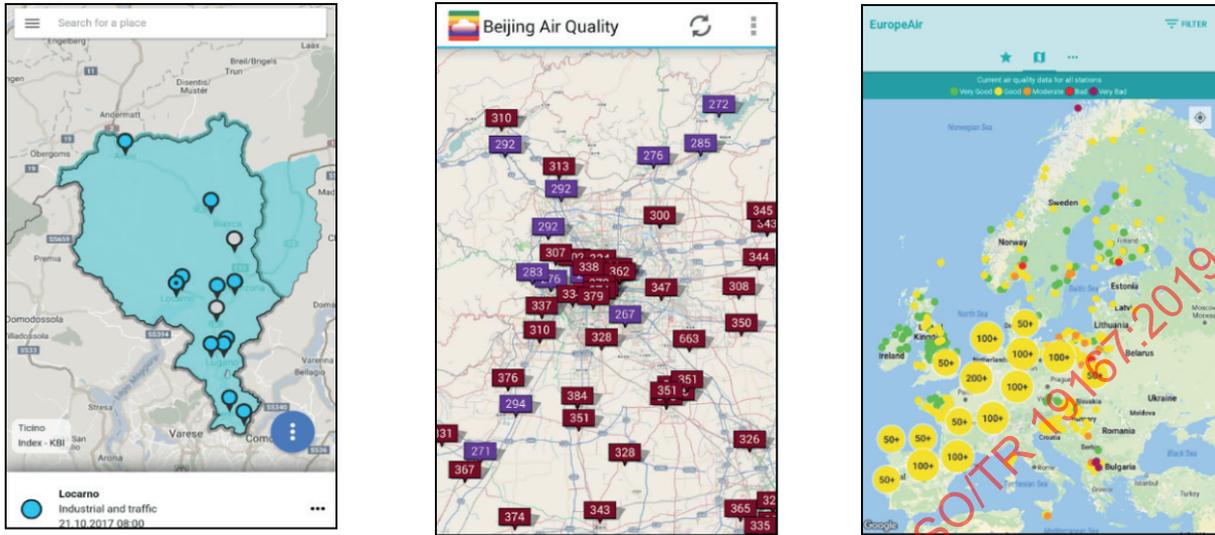


Figure A.1 — Examples of locational air quality information

Geospatial air quality information involves the use of an interactive map at on a regional, national, and global scale. To represent comprehensive air quality information, general maps, thematic maps, and satellite imagery are used either independently or in combination. In [Figure A.2](#), the air quality information is shown with a general map and map symbols. In this example, a map symbol indicates an air quality monitoring station, and its colour is specifically assigned according to the air quality index.

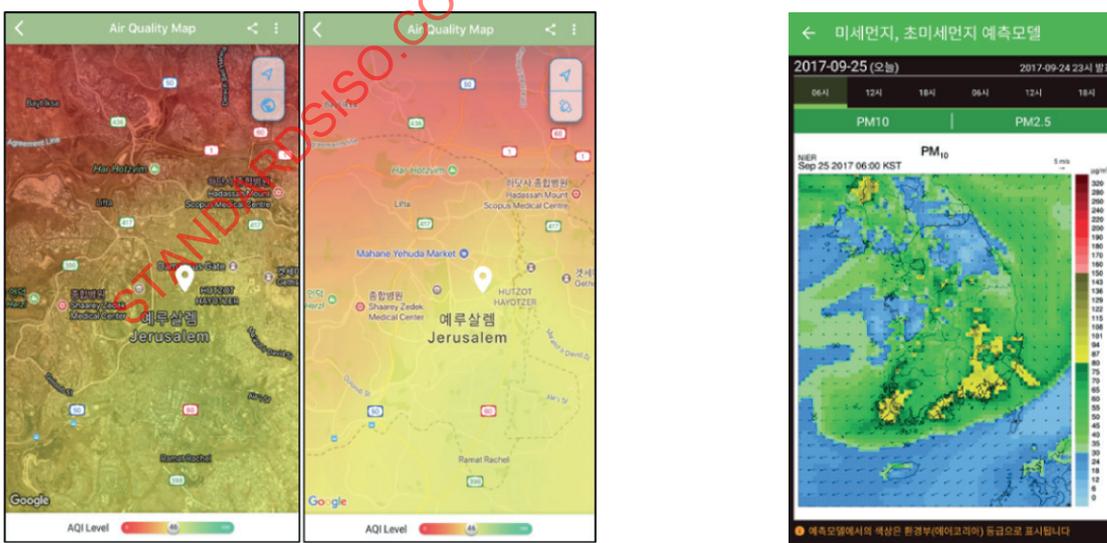
Thus, users can have insights into the air quality of individual cities, regions, and countries. This also enables air quality in a city to be compared with that of neighbouring cities.



(a) airCHek (Cercl'Air) (b) CAI (Beijing Air Quality) (c) EuropeAir (4sfera Innova)

Figure A.2 — Examples of geospatial air quality information on a regional, national, and global scale

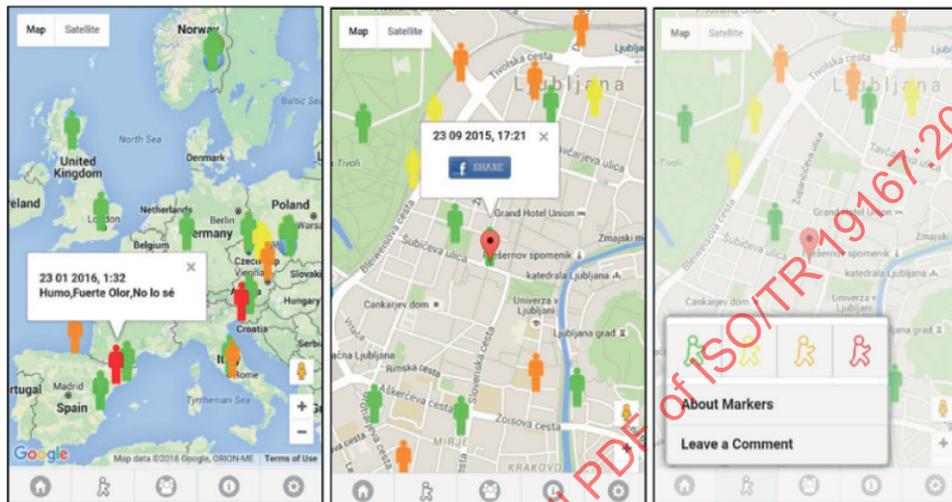
Geospatial air quality information in conjunction with an interpolation method or an atmospheric model is a powerful tool that not only supplements widely dispersed air quality monitoring stations, but also can forecast air quality information in advance. Interpolation (or modelling) results are transformed into a thematic map that depicts spatially seamless air quality conditions with different colours. In Figure A.3 (a), a machine learning algorithm is used to interpolate air quality data in near real-time. The interpolation results are overlaid with a general map or a satellite image. Also, in Figure A.3 (b), an atmospheric model is employed to forecast air quality for the next day. Thus, users can better prepare for their outdoor activities at their locations and regions of interest.



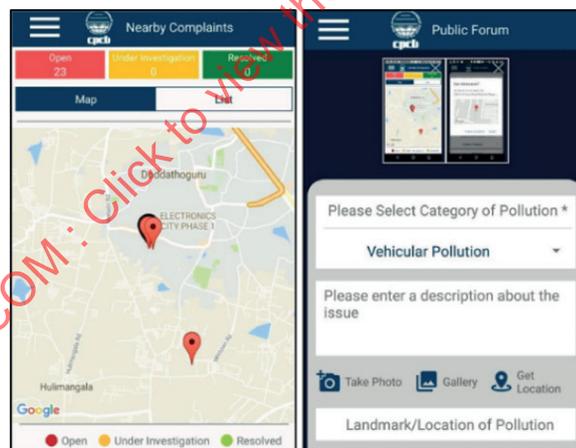
(a) Air Quality Index (BrezonMeter) (b) CAI (Siftworx)

Figure A.3 — Examples of geospatial air quality information with an interpolation method and an atmospheric model

Figure A.4 indicates that a mobile application can be a means for citizens to participate in environmental governance to improve air quality. A portable device with GNSS functionality allows users to express their perceptions of air quality at current locations. Likewise, an air quality monitoring station in Figure A.2, a user's location and perception are represented with a map symbol and a colour, respectively [Figure A.4 (a)]. Users can also leave comments, regarding assumed air pollution sources [Figures A.4 (a) and (b)]. The geospatial air quality information enables users to not only share public air quality opinions, but it also allows local authorities to shape their air pollution reduction policies and strategies.



(a) CityAir (NILU)



(b) National Air Quality Index (Sameer)

Figure A.4 — Examples of geospatial air quality information with a citizen's report