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City Air Management (CyAM)

July 2018

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Introduction

City Air Management (CyAM) by Siemens reflects a real change in how cities and people address the issue of air quality. Today, we have the technologies to significantly improve air quality, make both transport and industry cleaner, while digitalization is providing us with the data that we need to make better decisions.

In many of our cities, air quality is a growing problem, and one that has typically resided only within the scientific or regulatory part of city government. However, the issue of air quality is rapidly becoming a political issue – often linked with a roadmap to reduce carbon or greenhouse gas emissions by a fixed date that lies several decades in the future.

While these time horizons might seem distant, CyAM technology is here to move this discussion to the present. How are we, as a city, going to improve quality of life – in both the short and the longer term?

The Air Quality Challenge

Continuous urbanization has resulted in population growth, sprawling land use and changes in mobility behavior. Despite public transit investments, congestion is worsening globally. The sheer volume of inter- and intra-urban transportation has outpaced improvements in and customer uptake of clean transport technology.

As a result, air quality has deteriorated in many cities, large and small, and city leaders are accepting that, at its core, poor air quality is an issue of public health and wellbeing. However, it is also an issue of environmental justice: As the data show, air quality in cities tends to be worst in the poorest communities, and disproportionately affects vulnerable communities, such as the young and the elderly.

Fortunately, the deployment of sensors and digital analytics provide unique opportunities for city leaders to harness data to make better decisions and take action in the short term. New digital technologies, such as CyAM, will contribute to tangible improvements in local quality of life by enabling citizens to improve their health and make more informed decisions about how they travel, and by giving city leaders a better understanding of the causes and severity of local air pollution.

There is a massive difference in NOx tail pipe emissions between driving a diesel car or riding an electric bus down a city street. We at Siemens know that is not possible to change a city's infrastructure overnight. It takes time. But we also know that there are immediate measures that cities can implement if air quality is the strategic priority it should be. CyAM technology identifies actions to avert poor air quality in the short-term, simulates the impact of these measures and creates enough certainty around these impacts to foster proactive decision-making.

"As the data show, air quality in cities tends to be worst in the poorest communities, and disproportionately affects vulnerable communities, such as the young and the elderly."

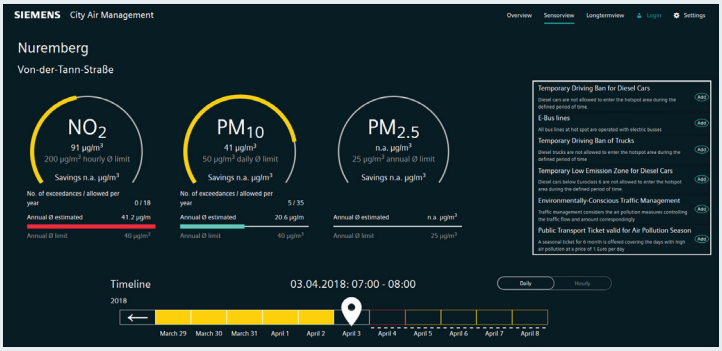
What CyAM will do:

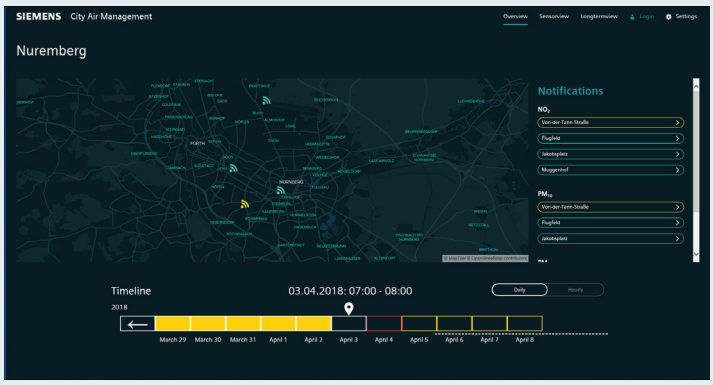
- Monitor the city-wide, hotspot emissions of all environmental sensors which have been integrated in the tool, focusing primarily on PM2.5, PM10 and NOx. Data is shown for each sensor on an hourly basis.
- Forecast air quality and inform city leaders through a dashboard about where, and by how much air quality is expected to exceed health or regulatory thresholds over the coming three days with 90-percent accuracy and up to five days at a level of 75-80%.
- Allow city leaders to simulate specific pre-defined emission-reducing actions against the expected emission levels in order to reduce the risk of exceeding emissions thresholds or key indicators.

The transparency and information derived from CyAM provides city leaders with a unique opportunity to:

- Engage residents in making contributions to improved air quality. This process is the beginning of a wider discussion about behavioral change and choosing more sustainable forms of transport in the future.
- Generate data and information on types of transport-related actions, and create a smart city technology roadmap that lays out which actions and technologies could have the best impact on air quality.
- Prove to citizens that the city is serious about tackling air pollution and that it is undertaking both short-term actions and medium-term planning to improve air quality.
- Move the conversation from emissions reductions by 2040 or 2050 to improving lives in 2018.

The following images illustrate the technology's capabilities: The first image is an overview of connected sensors across the city. The second image shows the emissions dashboard for one air quality sensor and highlights the actions that could be taken in that area to simulate the potential impact.





"The transparency and information derived from CyAM provides city leaders with a unique opportunity..."

Why Siemens?

We understand transport systems and their impact on how people move.

For example, in the UK, we are running a large part of London's traffic control system, rolling out e-vehicle charging infrastructure, and supporting Low Emission and Congestion Charging Zones. We are supporting trials of electric trucks in Sweden and the US, rolling out electric ferries and fishing boats in Norway and delivering travel apps in Berlin and Dubai. Together with Singapore, we are creating a digital hub using our cloud-based open IoT operating system, MindSphere.

In addition, Siemens has worked with several global cities, using our CyPT (City Performance Tool) to offer predictions for air pollution and greenhouse gas emissions and create actionable scenarios to improve both. Leaders have used this data to drive bold action in their cities:

"I included your report in the presentation that went to Council yesterday, and they unanimously adopted a goal to reduce GHGs by 30 percent by 2025! The work done by Siemens definitely had a role."

-– Mark Hartmann, Sustainability Director for Phoenix

Methodology

Siemens has developed intelligent software that relies on artificial neural networks to accurately predict the degree of air pollution in cities several days in advance. Based on its analytical capacities, the main drivers for air pollution are identified and monitored continuously in order to improve the prediction capabilities. The software aims to give cities the information needed to minimize and avoid pollution peaks before they are likely to happen, thus improving the quality of life.

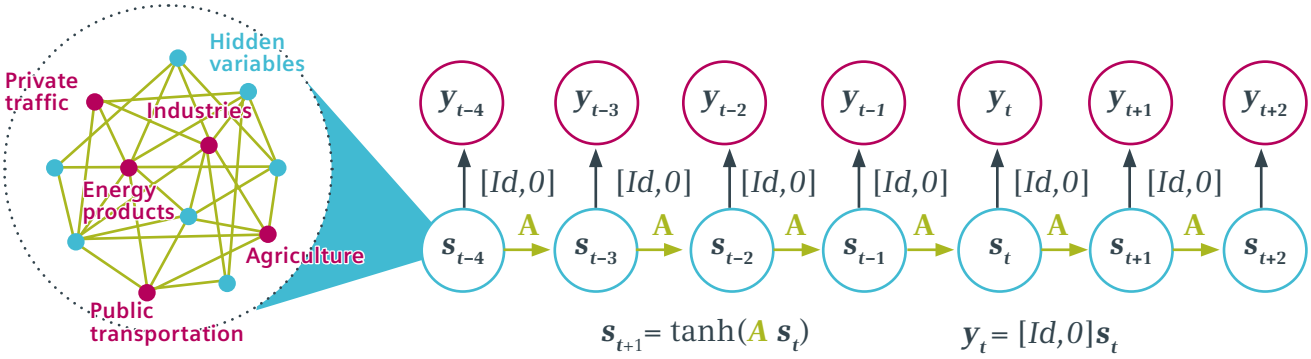
The CyAM system processes concentration measurements for gases and links the development of these emissions with additional available data sources such as weather data from the same period of time, which includes factors such as humidity, solar irradiation, cloud cover and temperature. Recurring events such as workdays and weekends, holidays, trade shows and sports events are also programmed into the model, as these affect traffic and emissions in a variety of ways.

The analytical and predictive technology for CyAM uses a platform for the development of neural networks with a proven 25-year track record. The system has been improved over time and is now able to produce and train recurrent neural networks of various types: neural networks for reinforcement learning as well as deep neural networks.

In the air pollution forecasting system, recurrent neural networks are used, which are well suited for this task. They also make it easier to uncover a great deal of previously unobserved, latent information about air pollution-causing factors from traffic, industries, agriculture, etc., in the internal dynamical model of the environment, which is built up during the training of the network (see example sketch below).

“The analytical and predictive technology for CyAM uses a platform for the development of neural networks with a proven 25-year track record.”

Based on all of the resulting data, as well as seasonal and immediate weather forecasts, the neural network has to learn how to predict the degree of air pollution. During the city-specific training process of the system, which includes hundreds of iterations, the program steadily reduces the difference between its forecasts and the actual levels of pollutants measured in the city’s atmosphere by changing the weightings of individual parameters.



Accuracy

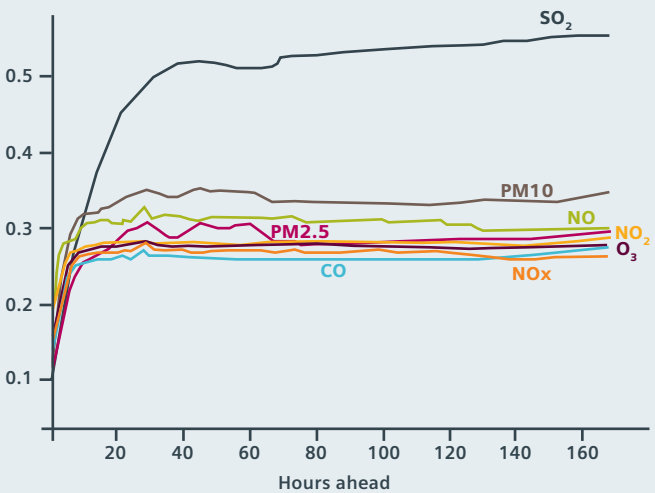
Already realized projects for air quality monitoring show an error rate of less than 20 percent for every hour of the following day. For five days in advance, the error rate was less than 28 percent. This success still can be improved as more data will be available over time and correlations will be even better understood.

More details on the accuracy of the air quality forecast can be found below. The diagram on the left describes the residual of the prediction compared to the variance of the data. The right side shows how many predictions are within standard deviation for each of the pollutants. As can be seen, the prediction accuracy is very high a few hours into the future and decreases after a prediction horizon of one day. After one day, the accuracy decreases only slowly with an increasing prediction horizon.

Based on the forecasting system, we also provide so-called sensitivities for each input factor of the model. The sensitivity is a measure of the dependency of the air pollution prediction to the respective input factor. For instance, if the sensitivity of the input factor wind speed is large for NO_2 and has a negative impact, then increasing the wind speed would lead to a reduction of NO_2. However, this information can also be quantified such that the precise correlation between wind speed and NO_2 can be determined.

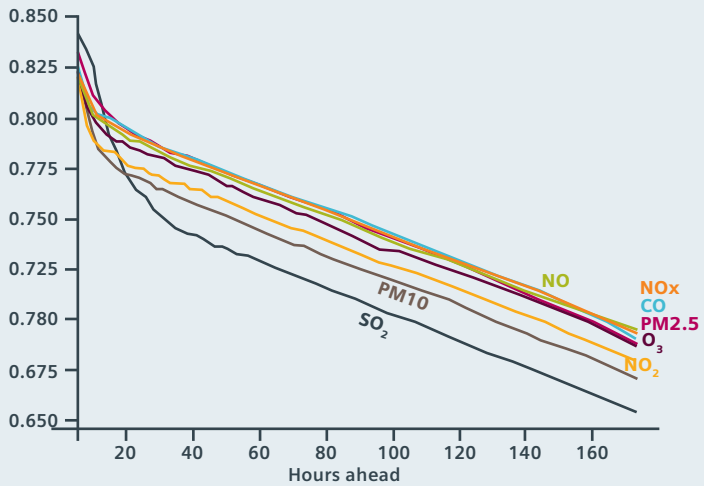
In summary, Siemens' CyAM forecasting system can predict the level of air pollution in the city for every hour up to the next five (and even seven) days by using all provided input information and modeling unobserved information, i.e., the underlying dynamic system, from the environment by using recurrent neural networks. The forecasting system delivers forecast values of the official network of air quality measurement stations and is not an air dispersion model. The system outputs also make it possible to infer the main drivers of the predicted air pollution and predict their impact.

Accuracy London Model



Prediction precision compared to the data variance for each pollution measure by hours into the future

70 – 85% accuracy dependent on prediction horizon and pollutant



Percentage of predictions within error threshold for each air pollution measure by hours into the future

Questions and Answers

What is CyAM in a nutshell?

City Air Management (CyAM) is a software dashboard that monitors air pollution via local sensors, forecasts air quality results five days in advance and simulates the potential impact of short-term measures over a five-day forecast period. The aim is to enable cities to comply with air quality emissions levels, create a positive dialogue with citizens and enable city leadership to demonstrate commitment as well as real action on air quality.

Our air pollution prediction is based on a sophisticated algorithm that works with an artificial neural network. Using data on historic air pollution, weather and traffic patterns, Siemens provides air quality forecast and concrete measure for three major KPIs, including: NOX, PM10 and PM2.5. Ozone or other indicators could be included.

Why Siemens?

Siemens works in more than 200 countries across the globe, supporting cities with their sustainable development and helping to improve the quality of life for millions of people. Over the years, Siemens has developed and implemented a broad portfolio of solutions and tools based around automation, electrification and digitalization focused on improving air quality. Our internal knowledge on technology has been embedded within CyAM.

Which measures can be simulated within CyAM?

There are 17 short-term levers that could be simulated within the CyAM standard model – depending upon the needs of the city. These measures include reducing the price of public transportation and encouraging public transport use, requiring that all buses in that area be electric or encouraging residents to work from home when possible. In addition to the short-term measures, there are 40 medium- to long-term transport levers that can serve as a forecasting and modeling tool, giving an outlook for the situation in 2025 or 2040.

What is the CyAM technology and service?

City Air Management is a cloud-based software suite. The dashboard has a modular and expandable IT architecture that allows for potential future innovation enhancements such as the introduction of additional historic and real-time datasets from traffic, the city events schedule or mobile air quality sensors.

“Over the years, Siemens has developed and implemented a broad portfolio of solutions and tools based around automation, electrification and digitalization focused on improving air quality”

SaaS (Software as a Service) – what does it encompass?

Siemens provides CyAM over the internet through a web interface. Siemens develops, manages and runs CyAM as its owner, and the city acquires the right to use the standardized service based on it.

As our SaaS solution resides in a cloud environment, it is easily scalable and facilitates the integration with other SaaS offerings. Compared to the traditional model, users do not have to buy another server or software, which ensures that costs and effort associated with upgrades and new releases are lower.

What is the city's role and what data will it need to provide?

The city would need to provide air quality sensor data, historic and real-time air quality data streams of all available measurement stations from a central database using standard database data interfaces. As part of future innovations, we would be open to exploring the introduction of other relevant data sets from other stakeholders, such as:

- Occupancy and delay data of public transportation
- Socio-demographic data, such as number of citizens living in an area, age, occupation
- Average commuting distance and time
- Surrounding construction sites
- Other city dashboards (e.g., public transportation)
- Any other data source that might impact on air pollution

How and where would CyAM be hosted?

CyAM is a cloud-based software suite that is built for Amazon Web Services (AWS). The dashboard and modular and expandable IT architecture allows for potential future enhancements such as the introduction of additional historic and real-time datasets from traffic, city events schedules or mobile air quality sensors.

How does the CyAM tool integrate data streams from other sources?

We have developed a standard API, and city sensor data would be uploaded to the cloud for feeding into the software. The software will be compatible with different types of sensors and is, in this respect, technology-agnostic.

Where is CyAM being used today?

Building on the initial forecasting tool, which utilized data from the air quality monitoring network in London, UK, we are now running a test installation in Nuremberg, Germany, including simulation of short-term measures at hotspot areas.

What is the timeline for the implementation of the solution?

In order to get the air quality forecasting system up and running, we estimate three months to set up and train the system in line with the methodology outlined above. This will include the following activities:

- Receipt of the historic and real-time air quality data streams of all available measurement stations from a central database using standard database data interfaces – our proposal assumes a data history of 12 months is available and the air quality database from the network of air quality monitoring stations will continue to be available during the term of the contract. In addition to our CyAM tool, we can offer to set up a network of intelligent measurement stations (see options Embedded City Box).

"As part of future innovations, we would be open to exploring the introduction of other relevant data sets from other stakeholders"

- Integrating weather forecast data for each station along the forecast horizon (also in hourly time buckets) – our proposal assumes the weather forecast provided by a service provider like Meteo Blue using standard interface (e.g., flat file transfer etc.) The forecast horizon naturally depends on the length of the weather forecast.
- Automate the input of these external data sets into the Siemens air quality forecasting system.
- Commence the set-up of key user authentications (the set-up time is dependent on the number of key users to be defined).
- Set up the storage system.

Questions and Answers (cont.)

The total time required for implementation and integration of the historical data is estimated at four months. In addition, we have allowed one month for the dashboard development.

How would the public engage with CyAM?

Our concept is based on communicating the air quality forecasts via a city service dashboard to key users, not via text alerts to citizens. We believe a dashboard delivers a more comprehensive and detailed visualization of the expected level of pollution at each of the monitoring stations and allows for easy comparison of alert levels and forecasting quality.

How the city communicates air quality to its citizens is completely up to the city. CyAM provides information for the city to create a dialogue, but it is up to city leaders to determine the form of that dialogue.

Do all of the levers assume 100 percent compliance? Or is there some possibility to show different impacts based on a range of assumptions about compliance?

CyAM can model different levels of compliance. Based on a range of assumptions, the tool can handle each level as an individual lever. The impact of the measures would be based on our internal technology know-how as well as a preliminary strategic study with the city to understand how compliance is enforced or the magnitude of change that could be delivered.

Will our city data be safe?

CyAM will not publicize any data, and data would reside on an AWS cloud. Sensor data and the dashboard will only be available to city-nominated users. Siemens is a large software company, and the security of data, including in cyberspace, is a critical part of our business.

How does our tool compare to EPA's Air Now and other air quality forecasting tools?

The EPA's Air Now uploads data from sensors across the USA and globally at US embassies and posts current air quality emissions levels as well as forecast emissions in particular zones. The website offers educational information for the general public, and registered users will receive email alerts if air quality is forecast to be poor.

"CyAM will create the knowledge base in terms of actions that a city could take, and it will enhance the dialogue being created through Air Now."

CyAM is different from Air Now as it will allow city management to simulate specific short-terms actions that could take place near to known emissions hotspots and across the city to reduce the likelihood that emissions ever exceed local guidelines.

CyAM could upload data from the same sensors that feed data into Air Now. CyAM will create the knowledge base in terms of actions that a city could take, and it will enhance the dialogue being created through Air Now.

Is there a limit on the number of sensors included in the network?

There is no defined limit on the number of sensors, but the sensors should be of a similar quality level, stationary and monitor the same indicators.

Addressing Air Pollution

2040-2050 Air Pollution Targets

CyAM technology focuses mainly on short-term measures. However, cities can also rely on Siemens' technology expertise and global database for their long-term planning with a City Performance Tool Air study (CyPT Air). This would be a preliminary study informing the formulation of assumptions used within the CyAM software.

In order to assess the effectiveness of medium- and long-term measures, cities may calculate the impact of approximately 40 transportation technologies on air pollution KPI's. Based on this data, more effective technology roadmaps and policy-making advice may be developed.

With this additional dataset, cities receive a complete picture of their pollutant emissions and, as a consequence, are able to tackle the problem more efficiently.

Having access to the forecasting KPIs at any time and being able to simulate the impact of short-term measures for specific days will make a big difference in the day-to-day battle against air pollution.

Furthermore, the possibility of simultaneously assessing the impact of both medium- and long-term measures on their city's overall emissions gives decisionmakers the knowledge required to make better long-term decisions.

"Having access to the forecasting KPIs at any time and being able to simulate the impact of short-term measures for specific days will make a big difference in the day-to-day battle against air pollution."

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