



(RESEARCH ARTICLE)



VayuIQ: Breathe smarter

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Abstract

The urban environment, particularly in rapidly growing cities, faces challenges such as poor air quality monitoring, lack of real-time awareness, limited citizen engagement in pollution control, and inadequate tracking of carbon emissions. Traditional AQI systems provide static data but fail to deliver actionable insights, carbon footprint visibility, or personalized recommendations. This project presents VayuIQ: Breathe Smarter designed to enhance environmental awareness and enable proactive decision-making through real-time data and AI-driven insights. The system is a web-based application that integrates real-time AQI data with a user-friendly interface for both citizens and authorities, along with a carbon tracker that monitors emissions and generates analytical reports. It incorporates Machine Learning-based analytics to predict pollution trends and assess risk levels. A smart alert system delivers personalized health recommendations, while the authority dashboard provides visualization of pollution hotspots and carbon reports for timely interventions. The system improves awareness, supports preventive actions, and enables smarter environmental management.

Keywords: Air Quality Monitoring; Machine Learning; Predictive Analytics; Smart Alerts; Carbon Tracking; Pollution Forecasting; Authority Dashboard; Report issue

1. Introduction

1.1. Background Motivation

Urban areas face rising air pollution, significantly impacting public health and overall quality of life. Existing systems often lack real-time insights and actionable guidance, limiting effective response. VayuIQ addresses these challenges by delivering accurate, real-time air quality monitoring with intelligent data analysis.

It provides predictive pollution analysis and personalized health alerts, enabling citizens and authorities to take timely actions. This improves awareness, reduces health risks, and supports smarter, data-driven environmental decision-making in rapidly growing urban areas.

1.2. Need for the Study

The increasing levels of air pollution in urban areas highlight the need for intelligent systems like VayuIQ for effective monitoring and management. Existing AQI systems lack real-time insights, predictive capabilities, and personalized guidance, limiting their impact.

There is a need for solutions that enable predictive analysis, carbon tracking, and actionable alerts, enhancing awareness, supporting timely interventions, and promoting healthier, data-driven environmental management practices.

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1.3. Objectives of the Study

The main objectives of this project are:

- To develop a real-time air quality monitoring system integrating AQI data and intelligent alerts for proactive environmental management.
- To implement machine learning models for accurate pollution prediction.
- To design a smart alert system providing personalized health recommendations and safety measures based on real-time air quality conditions.
- To build an authority dashboard for monitoring pollution hotspots.
- To enhance public awareness and promote data-driven environmental decisions.

2. Literature review

Existing air quality monitoring systems primarily focus on displaying AQI values, offering limited support for real-time decision-making and user engagement. Some recent approaches integrate Machine Learning and Predictive Analytics to forecast pollution trends, helping authorities plan interventions, but they often lack personalization and real-time responsiveness. Other solutions provide alert mechanisms for hazardous air conditions, yet these are mostly generic and do not deliver actionable or user-specific recommendations. A few platforms include environmental data visualization, but they fail to integrate carbon emission tracking and comprehensive reporting features. Overall, most systems address isolated aspects of air quality monitoring rather than providing a unified solution. This highlights the need for an intelligent system like VayuIQ that combines real-time monitoring, predictive analysis, carbon tracking, and personalized alerts.

2.1. Goyal et al. (2026). Air Quality Monitoring System Based on IoT

This study focuses on IoT-based continuous air quality monitoring using distributed sensors to detect pollutants like O₃, NO₂, CO, and PM. It enables real-time data collection, cloud processing, and alert generation, improving environmental awareness and supporting authorities in monitoring pollution levels effectively.

2.1.1. Methodologies and Algorithms

The study uses IoT sensors integrated with cloud platforms for data collection and transmission. Machine Learning algorithms are applied for pattern analysis, identifying pollution trends and supporting short-term predictions. Ability to analyze pollution data and generate insights.

2.1.2. Accuracy and Limitations

The study provides reliable real-time monitoring and trend analysis of air pollutants using IoT and analytics. However, it does not include personalized health recommendations, supports trend analysis but lacks explicit multi-day AQI prediction (e.g., 3-day forecasting), or a comprehensive authority dashboard for advanced visualization and decision support systems.

2.2. P Saha. (2025). Emerging Integration of Artificial Intelligence of Things (AIoT) in Air Pollution Monitoring and Management

This study focuses on integrating Artificial Intelligence with IoT for real-time air pollution monitoring and management. It highlights predictive modeling for pollution trends and identifies emission hotspots.

2.2.1. Methodologies and Algorithms

The study uses AIoT frameworks combining sensor data collection, machine learning models, and anomaly detection techniques to monitor pollution levels and predict trends, enabling data-driven environmental analysis and response mechanisms.

2.2.2. Accuracy and Limitations

The study provides reliable real-time monitoring and general prediction models but lacks precise short-term AQI forecasting and structured authority dashboards. It does not address personalized alerts or integrated carbon tracking systems.

2.3. Azizah et al. (2025). Internet of Things Based Air Quality Monitoring System with Automatic Notification

This study focuses on an IoT-based air quality monitoring system integrating multiple sensors and cloud computing to provide real-time pollution data, automated alerts, and dashboard visualization, supporting environmental monitoring and improving public awareness in urban areas effectively.

2.3.1. Methodologies and Algorithms

The study uses IoT sensors, cloud integration, and machine learning models including Weighted Class approach for prediction, along with real-time data processing and automated notification mechanisms to detect pollution levels and generate timely alerts.

2.3.2. Accuracy and Limitations

The study provides high accuracy in monitoring and prediction using Weighted Class technique. It does not include extended multi-day AQI prediction or advanced authority dashboards for deeper analytics and long-term decision-making support.

2.4. Nethra et al. (2024). Real-Time Weather Monitoring System with Air Quality Index (AQI) Tracking and Dynamic Visual Analytics

This study focuses on developing a real-time environmental monitoring system using APIs to track weather parameters and AQI data. It emphasizes dynamic visualization through interactive dashboards, enabling users to understand environmental conditions effectively and support real-time decision-making in urban and public health applications.

2.4.1. Methodologies and Algorithms

The study uses RESTful APIs, cloud-based data processing, Django backend, and Chart.js visualization. It collects AQI and weather data, processes JSON responses, and displays trends through interactive dashboards for user-friendly real-time environmental analysis.

2.4.2. Accuracy and Limitations

The study provides reliable real-time AQI monitoring and visualization. It does not include predictive AQI forecasting such as 3-day prediction, carbon tracking, or an advanced authority dashboard for decision-making and proactive pollution control.

2.5. Raghavendra Khot, Vidya Chitre. (2017). Survey on Air Pollution Monitoring Systems.

This study focuses on real-time air quality monitoring systems that measure pollution parameters and support timely decision-making for authorities. It highlights the importance of continuous monitoring in urban areas to evaluate health impacts and environmental risks, but lacks predictive AQI analysis.

2.5.1. Methodologies and Algorithms

The study uses sensor-based data collection and real-time monitoring techniques to analyze pollution parameters. It focuses on data acquisition and visualization rather than implementing machine learning models for multi-day AQI prediction or intelligent forecasting.

2.5.2. Accuracy and Limitations

The study provides accurate real-time pollution monitoring and supports basic decision-making. It does not include three-day AQI prediction, personalized alerts, carbon tracking, or advanced authority dashboards for comprehensive environmental analysis and proactive management.

2.6. Scalability Comparison of Existing and Proposed Systems

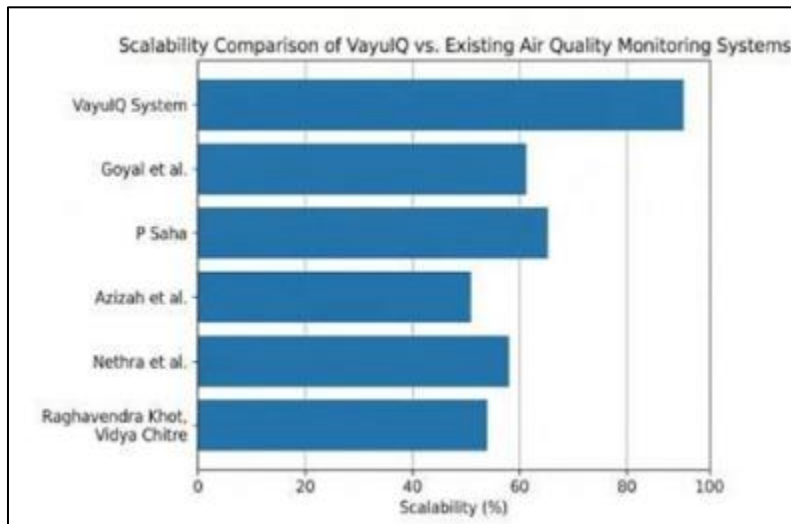


Figure 1 Comparison of Scalability of Existing and Proposed Systems

Figure 1 The graph shows that existing systems have limited scalability due to their static or theoretical nature, while the proposed system achieves higher scalability due to its web-based architecture and real-time processing capabilities.

2.7. Comparison of Accuracy of Existing and Proposed Systems

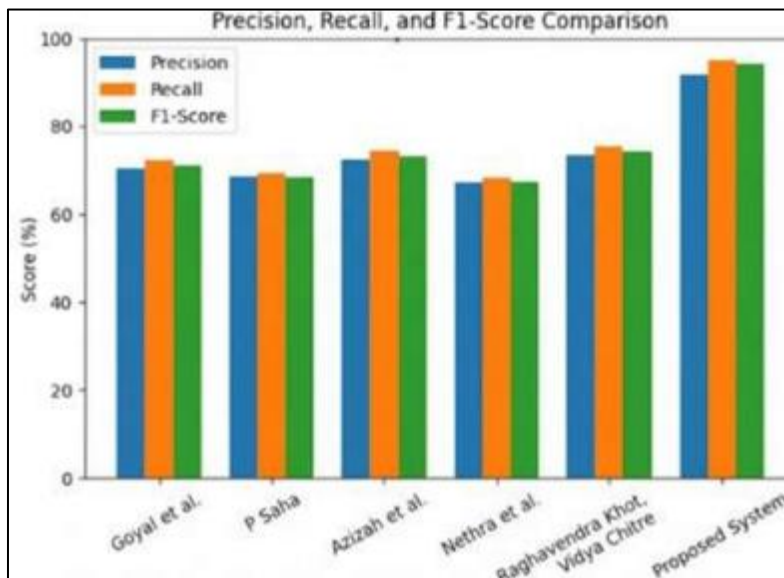


Figure 2 Comparison of Precision, Recall, F1-Score of Existing and Proposed Systems

Figure 2 The graph compares Precision, Recall, and F1-Score of existing inventory management approaches with the proposed system. Existing methods show moderate performance due to limited automation and lack of predictive intelligence. In contrast, the proposed system achieves higher Precision, Recall, and F1-Score by integrating Machine Learning and real-time air-quality monitoring, ensuring more accurate and reliable decision-making.

2.8. Comparative Analysis of Existing Systems with Proposed Model

Table 1 Comparative Analysis of Existing Research on Inventory Management Systems

Name of the Paper	Year	Techniques Used	Accuracy	Limitations
Air Quality Monitoring System Based on IoT	2026	IoT sensors, Cloud integration, ML- based trend analysis	High	No 3-day AQI prediction, no personalized alerts, lacks authority dashboard
AIoT in Air Pollution Monitoring and Management	2025	AIoT frameworks, ML models, Anomaly detection	High	No precise short-term prediction, lacks structured authority dashboard, no carbon tracking
IoT-Based Air Quality Monitoring with Automatic Notification	2025	IoT sensors, Cloud computing, Weighted Class ML algorithm	High	No multi-day AQI prediction, lacks advanced authority dashboard
Real-Time AQI Tracking with Dynamic Visual Analytics	2024	APIs, Cloud processing, Django, Chart.js visualization	Moderate	No AQI prediction, no carbon tracking, lacks authority-Level decision support
Survey on Air Pollution Monitoring Systems	2017	Sensor-based monitoring, Data analysis, Visualization	Moderate	No predictive analytics, no 3-day AQI forecast, no alerts or authority dashboard

As evident from Table 1, existing air quality monitoring systems provide reliable data collection and visualization but primarily focus on isolated functionalities such as real-time monitoring, basic alerts, or trend analysis. Most approaches lack advanced capabilities like multi-day AQI prediction, personalized health recommendations, carbon emission tracking, and comprehensive authority dashboards. Additionally, limited integration of predictive analytics restricts proactive decision-making and effective environmental management. In contrast, the proposed VayuIQ system overcomes these limitations by integrating real-time AQI monitoring with Machine Learning-based three-day prediction, smart alerts, and carbon tracking. The inclusion of an advanced authority dashboard further enhances decision-making, enabling timely interventions, improved public awareness, and efficient, data-driven environmental management.

3. Methodology

The proposed VayuIQ system consists of multiple modules, including real-time AQI Monitoring, Pollution Prediction, Carbon Tracking, Smart Alerts, User Interface, and Authority Dashboard, integrated into a unified web-based platform. These modules operate within a structured workflow, beginning with data collection from APIs and sensors, followed by centralized storage and processing. The system continuously monitors air quality levels, predicts pollution trends for the next three days using Machine Learning, tracks carbon emissions, and generates alerts and reports. The authority dashboard visualizes pollution hotspots and supports decision-making. This integrated approach enables efficient, automated, and data-driven environmental monitoring, enhancing public awareness, supporting timely interventions, and promoting healthier urban living.

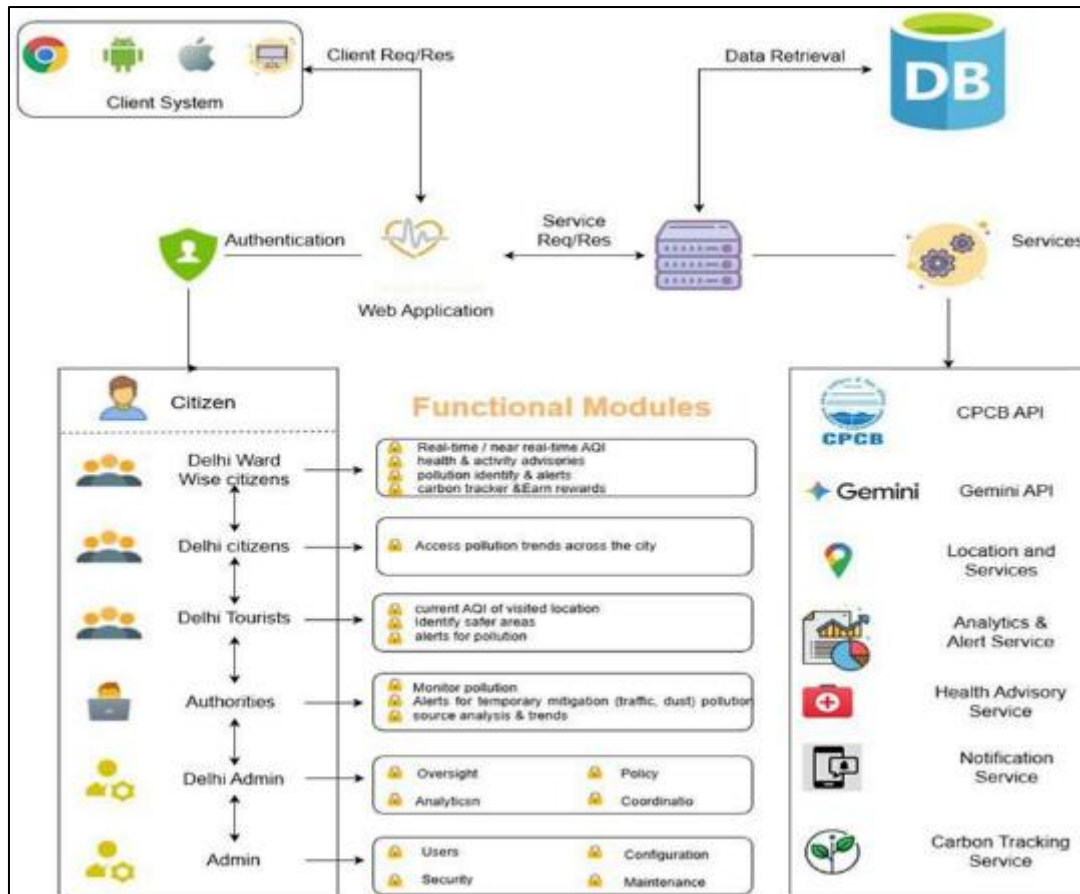


Figure 3 System Architecture for Proposed System

The proposed system follows a structured workflow that integrates real-time air quality monitoring, Machine Learning-based pollution prediction, proactive insights, and user-centric guidance for both citizens and authorities.

- **Step 1:** User Login and Authentication

The process begins when the citizen or authority logs into the VayuIQ system. The system verifies credentials and grants secure access.

- **Step 2:** Location Request and Data Acquisition

The user requests location-based services. The system fetches real-time AQI data using APIs based on the user's geographic location.

- **Step 3:** Real-Time AQI Monitoring

The system processes incoming environmental data and displays real-time AQI values to the user through the interface.

- **Step 4:** Health Advisory Generation

Based on AQI levels, the system generates synchronized health precautions and personalized safety recommendations.

- **Step 5:** Pollution Source Identification

The system analyzes pollution data to identify possible sources and displays insights for better understanding.

- **Step 6: Severity Detection and Alert System**

If pollution levels exceed thresholds, the system detects severity and triggers alerts to notify both users and authorities.

- **Step 7: Authority Notification and Response**

Authorities receive alerts and access dashboards to monitor pollution hotspots and take mitigation actions.

- **Step 8: Carbon Tracking Module**

Users can input activities, and the system calculates carbon emissions, promoting awareness and eco-friendly behavior.

- **Step 9: Rewards and User Engagement**

Based on eco-friendly actions, users earn rewards, encouraging participation in environmental improvement.

- **Step 10: Report Generation and External Reporting**

Users and authorities can submit reports on pollution sources, which are forwarded to relevant authorities for action.

- **Step 11: Continuous Monitoring and Updates**

The system continuously updates AQI data, alerts, and dashboards, ensuring real-time responsiveness and data-driven environmental management.

4. Results and discussion

The proposed VayuIQ system was tested under various simulated conditions to evaluate its performance in air quality monitoring and environmental decision support. The system integrates a web-based interface, real-time AQI data processing, Machine Learning-based pollution prediction, and smart alert mechanisms to ensure efficient operation. The results demonstrate that the system effectively provides accurate air quality insights, predicts pollution trends, and supports timely actions for both citizens and authorities. It also enables carbon tracking and generates meaningful insights across scenarios such as high pollution levels, risk detection, and preventive advisory, enhancing overall environmental awareness and decision-making efficiency.

4.1. Initial Display



Figure 4 Initial Display

The above figure 4 displays the system login interface showing citizen login/registration and authority login access.

4.2. Citizen Dashboard



Figure 5 Citizen Dashboard

The above figure 5 displays the VayuIQ citizen dashboard showing real-time AQI levels, pollution hotspots, and environmental conditions. It includes features such as carbon tracking, dynamic health advisories, and AI-based pollution prediction. The dashboard provides alerts for hazardous air conditions and suggests preventive measures. It also visualizes location-based air quality data to support user awareness and safe decision-making.

4.3. Authority Dashboard



Figure 6 Authority Dashboard

The above figure 6 displays the VayuIQ authority dashboard showing pollution hotspots, AQI levels, and incident reports. It includes features such as real-time monitoring, global telemetry, and city-wide AQI trend analysis.

4.4. Carbon Tracker



Figure 7 Carbon Tracker

The above figure 7 displays the VayuIQ carbon tracker module showing user impact score, eco-actions, and community engagement. It includes features such as logging eco-friendly activities and tracking carbon footprint reduction.

4.5. Report Issue

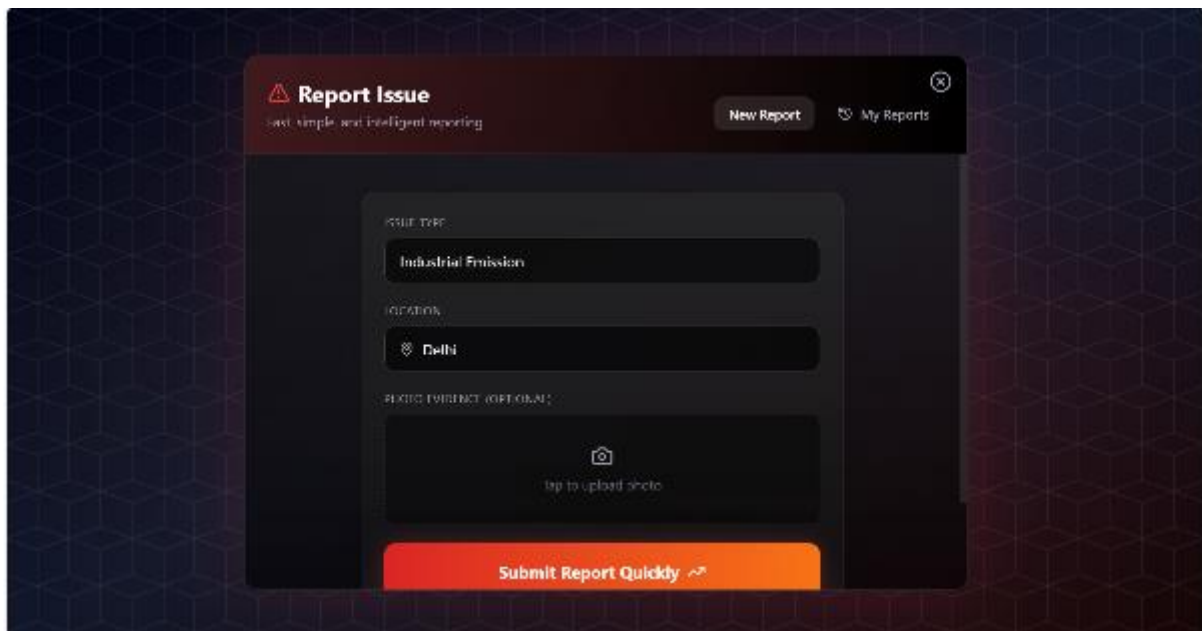


Figure 8 Report Issue

The above figure 8 displays the report issue module allowing users to submit pollution-related complaints quickly.

It is designed with a simple interface that takes less than 10 seconds to fill. Users can report issues such as emissions, waste burning, or pollution sources.

Rewards are provided for submitting valid reports, encouraging active citizen participation.

4.6. 3-Day AQI Forecasting



Figure 9 3- day AQI Forecasting

The above figure 9 displays the AQI 3-day forecasting module showing predicted air quality trends. It uses Machine Learning to analyze historical and real-time data for accurate short-term predictions.

Table 2 Functional and Performance Testing of the Proposed System

Test Case ID	Module	Test Description	Expected Output	Status
TC-001	Authentication	Valid user login	User successfully logged in	Pass
TC-002	Authentication	Invalid login attempt	Error message displayed	Pass
TC-003	AQI Monitoring	Fetch real-time AQI data	AQI displayed correctly	Pass
TC-004	Location Module	Detect user location	Accurate location-based AQI shown	Pass
TC-005	Prediction Module	3-day AQI forecasting	Forecast generated successfully	Pass
TC-006	Alert System	High pollution detection	Alert notification triggered	Pass

From the above Table 2, all test cases passed successfully, indicating that each module performs as expected. The system demonstrates stable, accurate, and reliable performance under different conditions.

5. Conclusion

The proposed VayuIQ system demonstrates how Machine Learning and Predictive Analytics can enhance air quality monitoring and environmental decision-making in urban areas. By integrating real-time AQI monitoring, three-day pollution forecasting, carbon tracking, and smart alert mechanisms, the system improves public awareness and enables proactive responses to pollution risks.

The system achieves its core objectives, including:

- Accurate real-time air quality monitoring
- Pollution prediction using Machine Learning
- Effective carbon tracking and reporting
- Smart alerts with personalized health recommendations
- Advanced authority dashboard for decision support

Overall, VayuIQ provides a reliable and scalable solution for smart environmental management, promoting healthier living and enabling data-driven actions for pollution control.

5.1. Future enhancement

The system can be further enhanced by integrating multi-city support to enable large-scale monitoring and comparison of air quality across regions. Integration with government and municipal systems can allow faster mitigation actions and policy implementation. Advanced Machine Learning models can be incorporated to improve the accuracy of multi-day AQI prediction and risk analysis. Developing a mobile application can enhance accessibility and real-time user engagement. Cloud deployment can ensure scalability, reliability, and secure data management. Additionally, features such as real-time emergency alerts, deeper carbon footprint analytics, satellite data integration, and advanced authority dashboards can further strengthen decision-making and enable more effective environmental management.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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