Chapter 10
Smart Carbon Emission Monitoring and Forecasting for Sustainable Logistics

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ABSTRACT

Sustainable logistics demands efficient and scalable systems for monitoring and forecasting carbon emissions. This work presents a Smart Carbon Emission Monitoring and Forecasting System (SCEMFS) for real-time detection of gases like CO_2, CH_4, NH_3, and VOCs using MQ-series sensors (MQ-2, MQ-7, MQ-9, MQ-135) integrated with a microcontroller. The collected data is used to train machine learning models—decision trees, random forests, SVM, and neural networks—for accurate prediction and classification of gas concentrations. Real-time analytics

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enables early intervention and improved environmental compliance. The system is scalable and suitable for various logistics settings, contributing to reduced carbon footprints and promoting sustainability in supply chain operations.

1. INTRODUCTION

Rapid industrialisation has increased carbon emissions while also fostering economic expansion and urbanisation. Achieving sustainability goals in urban settings requires a balance between economic development and carbon reduction measures (Xu et. al, 2023). Many industries have flourished because of industrialisation, which has also boosted global incomes and population levels (Saba et. al, 2023). The global economy over the last two hundred years has been driven by the extraction of natural resources and the manipulation of biogeochemical cycles (Rees et. al, 1989). The world's population is projected to reach 9.9 billion in 2050, up from 7.8 billion in 2020, driven by growing living standards. As a result, there will be a 70% increase in food consumption and an 80% increase in energy use (Wang, F. et. al, 2021). In addition, when planning the city's future, it's essential to build environmentally friendly facilities and attend to important human development factors like the number of bike lanes, the accessibility of educational institutions, and green infrastructures (Naumann, S et. al, 2021). As a result of these environmentally conscious renovations, city planners are thinking about how to gauge how happy the public is with the Net-Zero Carbon City (NZCC) transition (Szczepańska, A et. al, 2023).

Furthermore, NZCC initiatives are vital for accomplishing the UN's Sustainable Development Goals (SDGs), particularly SDG 11, which aims to make cities safer, more resilient, and more sustainable so that surrounding communities can live more conveniently (Lützkendorf, T et. al, 2019). The future of urban areas depends on achieving near-zero carbon emissions, as these pollutants contribute to climate change and global warming (Hansen, et. al, 2013). On the other hand, the world has already been warned about the negative effects of early industrialisation, with evidence of rising carbon dioxide emissions leading to more frequent and severe weather events (Sarkodie, S.A. et. al, 2020). Reducing emissions of greenhouse gases (GHGs), especially CO2, requires immediate action. If we want to study the spatiotemporal patterns in CO2 and find out how effective emission reduction strategies are, we need to monitor carbon emissions often using trustworthy datasets (An et. al, 2022). In the context of Net-Zero Carbon Cities (NZCCs), Biber and Krogstie (2021) highlighted the significance of developing frameworks for data-driven technologies (Bibri, S.E et. al, 2021). To track the present state of cities and foretell their future developments, data-driven approaches enable digital visualisation tools (Seto K.C. et.al, 2021) Modern cities are becoming smarter and more livable as a result of this

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