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Evaluating air quality efficiency in the major Indian cities using a directional distance function approach

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Abstract
Background: The ongoing advancements in modern society have negatively impacted air quality, and India is one of the worst affected countries. This study aimed to evaluate the efficiency of maintaining air quality in 10 major Indian cities.
Methods: The present study employed a directional distance function (DDF) within the framework of data envelopment analysis (DEA) to evaluate the efficiency of 10 major cities including Chennai, Delhi, Bengaluru, Ahmedabad, Hyderabad, Jaipur, Lucknow, Patna, Gurugram, and Thiruvananthapuram from January 01, 2018 to December 31, 2019.
Results: The results indicate that air pollution is a significant issue in most cities in India. Thiruvananthapuram, Bengaluru, and Chennai were identified as the most efficient cities in terms of air quality for both 2018 and 2019 whereas Ahmedabad was noted as a purely inefficient city during the same period. Moreover, it was revealed that cities in the northern (Delhi, Lucknow, Patna), western (Ahmedabad), and northwestern (Jaipur, Gurugram) parts of India had higher levels of air pollution compared to the southern (Chennai, Bengaluru, Hyderabad, Thiruvananthapuram) part of India.
Conclusion: There are significant disparities in air quality efficiency among the cities, revealing that southern cities perform better than their northern, western, and northwestern counterparts. It emphasizes the need for targeted interventions to improve air quality, particularly in cities like Delhi, Ahmedabad, and Jaipur.
Keywords: Air quality index, Air quality efficiency, Directional distance function, Data envelopment analysis
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Introduction

Air pollution remains a global environmental concern, particularly in India and other developing countries (1). India is one of the most polluted nations worldwide, with numerous cities facing environmental challenges due to increased air pollutant concentrations (2). Several Indian cities have reported exceeding levels of air pollutants, including respirable suspended particulate matter, carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), suspended particulate matter, and nitrogen dioxide (3,4). These pollutants can have serious consequences on human health, leading to breathing problems, headaches, dizziness, type 2 diabetes, and even heart problems (5-7). In recent studies on outdoor air pollution, the primary attention has focused on PM-related air pollution, particularly particles with a diameter of less than 2.5 µm, which can penetrate lung tissue and cause both local and systemic effects (8-11). The primary pollutants that impact human health include $PM_{2.5}$, PM_{10}, CO, SO_2, O_3, and nitrogen oxides (NO_X) (12). Apart from affecting human health, these pollutants also can contribute to global warming through the greenhouse effect and lead to losses in ecosystems.

In India, air pollution has had devastating effects, causing approximately 1.24 million deaths (13). The population is significantly affected by various diseases and health conditions due to air pollution. The effect of air pollution is associated with chronic obstructive pulmonary disease, as well as symptoms such as coughing, breathlessness, wheezing, asthma, respiratory illness, and elevated hospitalization rates. These immediate health impacts, however, are interconnected with the prolonged consequences of air pollution, which involve cardiovascular diseases, chronic asthma, cardiovascular mortality, and pulmonary insufficiency. Furthermore, air pollution appears to inflict diverse harmful health