Wiley
Modelling and Simulation in Engineering
Volume 2024, Article ID 3226125, 14 pages
https://doi.org/10.1155/mse/3226125

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Research Article

Analyzing the Effect of Variable Transportation Load on CO_2 Emissions in Distribution Networks

A Multifactorial Analysis

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Received 17 April 2024; Accepted 24 October 2024

Academic Editor: Chao Bao

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The global supply chain relies on road, land, and air transport, significantly contributing to greenhouse gas emissions. Various measures have been proposed to reduce these emissions, including energy taxes, environmentally friendly vehicles, and optimized transportation loads. Current optimization mainly considers fixed loads and vehicle types to reduce CO_2 emissions. However, dynamic loads in distribution networks and their interactions with factors like distance and vehicle type have not been studied. The present work contributes by (a) extending a vehicle routing problem (VRP) database to include vehicle type and load size data; (b) developing a mathematical model for emissions based on traveled distance, vehicle type, and load size; (c) creating a multivariate database of the emissions considering optimal routing; and (d) analyzing the database to identify key factors influencing emissions. A factorial analysis determined that vehicle type, load size, and traveled distance are the main factors associated with CO_2 emissions. By coding and rearranging the database considering three levels for each main factor, a 3^k full factorial design was developed to analyze the interactions of these factors and their effect on CO_2 emissions. The results of the analyses corroborate that optimizing vehicle utilization and minimizing routes, which depend on optimal load, distribution routes, and infrastructure planning, are recommended actions to reduce emissions.

Keywords: CO_2 emissions; dynamic load change; sustainability of supply chain; vehicle routing problem

1. Introduction

The transportation sector is directly associated with the emission of air pollutants such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NO_x), and sulfur dioxide (SO_2) [1–3]. These emissions contribute to respiratory disease, cardiovascular disease, cancer, and global climate change [3, 4].

Because its dominant energy source is based on fossil fuels, estimated to produce 3.0 kg of greenhouse gas (GHG) per liter of combusted fuel, the transportation sector is considered a major generator of global emissions of CO_2 and GHG [2–4]. In this context, road transportation is associated with 75.0% of CO_2 emissions [2]. This situation will likely worsen as transportation increases with economic development and population density. In fact, rapid urbanization results in more dependence on fossil fuel consumption, increasing the number of vehicles and congestion, pollution, consumption of other nonrenewable assets, and traffic accidents [5, 6].

Reduction of these pollutants is complex due to economic, social, and industrial factors. Among the different