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Beyond the Shortest Path: Artificial Intelligence and the Future of Sustainable Vehicle Routing

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Abstract

The Vehicle Routing Problem (VRP) is one of the most extensively studied combinatorial optimization problems in operations research, aiming to determine the most efficient set of routes for a fleet of vehicles serving a given set of customers under various constraints such as capacity, time windows, and delivery precedence. Since its formal introduction in the 1950s, the VRP has evolved into a broad family of variants, reflecting the increasing complexity of real-world logistics and supply chain operations. This study provides a conceptual overview of the VRP, tracing its evolution from classical exact and heuristic methods toward contemporary approaches driven by artificial intelligence, including machine learning-based route prediction, reinforcement learning for dynamic routing, and hybrid metaheuristics combining data-driven learning with traditional optimization. Particular attention is given to the growing intersection between VRP research and sustainability objectives, such as green vehicle routing, electric vehicle fleet optimization, and carbon emission minimization, which have become central concerns for businesses under increasing environmental and regulatory pressure. The paper discusses how these emerging approaches enhance decision-making flexibility, scalability, and responsiveness to real-time disruptions compared to traditional static models. By synthesizing recent developments, this study aims to offer researchers and practitioners a clearer understanding of current trends and future research directions in vehicle routing, positioning it as a strategic tool not only for operational efficiency but also for sustainable and resilient supply chain management.

Keywords: Vehicle Routing Problem; Artificial Intelligence in Logistics; Sustainable Supply Chain; Green Vehicle Routing; Metaheuristic Optimization