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Travelling Salesman Problem Applications for Electric Vehicle Routing Within Smart Campuses

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Abstract

Rapid expansion of smart infrastructure and sustainability initiatives within higher education institutions has intensified the need for efficient and intelligent transportation management in campus environments. Large university campuses operate as complex mobility ecosystems where continuous movement of shuttle vehicles, maintenance fleets, logistics units, and service vehicles occurs across numerous facilities such as academic buildings, laboratories, hostels, and administrative centers. Electric vehicles increasingly serve as a sustainable alternative for campus transportation due to reduced emissions, improved energy efficiency, and alignment with green campus policies. Operational performance of such electric vehicle fleets strongly depends on effective route planning because of constraints associated with battery capacity, charging infrastructure availability, and energy consumption patterns. Optimization approaches based on the Travelling Salesman Problem provide a powerful framework for addressing routing challenges where vehicles must visit multiple locations while minimizing travel distance, operational cost, and energy usage. Integration of TSP-based models within smart campus mobility systems enables efficient coordination of shuttle transportation, maintenance services, delivery operations, and facility management activities. Advanced computational techniques including heuristic and metaheuristic algorithms improve routing performance in complex transportation networks where conventional optimization methods encounter computational limitations. Algorithmic approaches inspired by swarm intelligence, particularly Ant Colony Optimization, offer adaptive and scalable solutions for large routing networks by simulating collective decision-making behavior observed in natural systems. Exploration of these optimization strategies within smart campus mobility environments supports development of intelligent routing frameworks capable of improving transportation efficiency, reducing operational costs, and promoting sustainable mobility practices. Analytical perspectives presented in this chapter highlight the role of TSP-based optimization models in designing energy-efficient electric vehicle routing systems for modern campus infrastructures while addressing operational challenges associated with large institutional mobility networks.

Keywords: Travelling Salesman Problem, Electric Vehicle Routing, Smart Campus Transportation, Ant Colony Optimization, Swarm Intelligence, Sustainable Mobility Systems.

Introduction

Large university campuses operate as complex and dynamic environments that accommodate extensive academic, administrative, and residential activities within geographically distributed spaces. Movement between academic departments, research laboratories, libraries, residential hostels, administrative blocks, and recreational facilities generates continuous transportation demand across campus regions [1]. Rapid growth in student enrollment, expansion of research infrastructure, and development of new academic facilities increase mobility requirements within institutional environments [2]. Campus transportation networks must support daily movement of thousands of individuals as well as service vehicles responsible for logistics, maintenance operations, and administrative functions. Efficient mobility management therefore represents a critical component of campus infrastructure planning [3]. Traditional transportation systems within many campuses rely heavily on conventional fuel-based vehicles and unstructured travel patterns, which often lead to congestion, increased travel time, and environmental impact [4]. Sustainable mobility strategies have therefore gained increasing attention within higher education institutions that seek to create environmentally responsible and technologically advanced campus ecosystems [5].

Electric mobility solutions have emerged as an important component of sustainable transportation initiatives within modern campuses. Electric vehicles provide several advantages including reduced greenhouse gas emissions, lower operational noise levels, and improved energy efficiency compared with conventional internal combustion vehicles [6]. Adoption of electric shuttle buses, service vehicles, delivery carts, and maintenance fleets within campus transportation systems contributes to environmentally sustainable operations while supporting institutional sustainability commitments [7]. Campus environments present favorable conditions for electric mobility deployment due to predictable travel patterns, controlled geographic boundaries, and relatively short travel distances between major facilities [8]. Such operational characteristics enable effective integration of electric vehicles within campus transportation networks. Battery capacity limitations and charging infrastructure availability nevertheless introduce operational challenges that influence route planning and vehicle scheduling [9]. Efficient management of electric vehicle fleets therefore requires structured optimization frameworks capable of minimizing travel distance while ensuring reliable completion of service tasks [10].