TSP model for electric vehicle deliveries, considering speed, loading and path slope.

Maud Bay and Sabine Limbourg

University of Liege (ULg), HEC Management School, QuantOM, Rue Louvrex 14, 4000 Liège, Belgium
Corresponding author: sabine.limbourg@ulg.ac.be

In the current Transport White Paper, the European Union presents a roadmap for a more competitive and sustainable European transport system. Concerning Urban Freight Transport, responsible for about a quarter of CO_2 emissions of the transport sector, one of the goals of the EU is to achieve essentially CO_2-free city logistics in major urban centres by 2030 by developing and deploying new and sustainable fuels and propulsion systems. The gradual phasing out of 'conventionally-fuelled' vehicles from the urban environment contributes to reduce oil dependence, greenhouse gas emissions and local air and noise pollution. To meet European air quality standards, authorities of some major European cities have already introduced Low Emissions Zones where access to urban areas is limited to freight vehicles that meet certain emissions standards.

Greater use of low-emission urban trucks based on electric, hydrogen and hybrid technologies would reduce air emissions, but also noise, letting to use road infrastructure more efficiently by making night deliveries and avoiding morning and afternoon peak periods. In addition to their role in the reduction of polluting emissions, the development of low-emission vehicles also allows to mitigate the dependence of the transportation sector to high fossil fuel prices. Electric vehicles have the potential to be powered by renewable energy sources such as wind and solar energy.

However, weaknesses can be found in the limited capacity of the battery and the time needed to recharge, and consequently, the limited driving range of electric vehicle. The main sources for final energy consumption are the vehicle size and the engine characteristics, the load factor, the driving pattern, the gradient which represent the average topology of the country, the speed and the acceleration. To maximize the driving range, a routing model, which aims at minimizing the energy consumption, has to be developed.

Our paper focus on the Electric Vehicle Traveling Salesman Problem (EV-TSP): given *n* cities, find the shortest tour, i.e., the shortest directed cycle containing all cities. The classical objective is to minimize the cost tour scheduling to fulfill delivery requests at each location. In this paper we consider the energy cost and we present an extension of the classical problem to minimize the remaining storage capacity of all electric vehicles at the destination node, knowing that there is no recharge operation on the tour. The objective function accounts not just for the travel distance but also on the load of the vehicle and on its speed while the energy consumption of the engine additionally depends on the path to travel, on the slope of the roads and on the vehicle specifications. Moreover, negative consumption that may happen due to regenerative breaking and kinetic energy capture on downhill paths is taken into consideration. Mathematical model is described and computational experiments are performed.

KEYWORDS: electric vehicles, energy minimization, sustainable delivery, battery management, travelling salesman problem