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Green Logistics and Crowd-shipping: Challenges and Opportunities

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In recent years, we have witnessed a growing interest in environmental problems related to polluting emissions, noise and congestion in the transportation logistics. In this context, developing environmentally friendly and efficient transport and distribution systems, defined in such a way to ensure the best trade-off between cost minimization and negative environmental externalities reduction, represents an important challenge for many countries. In this dissertation we focused on two new branches of logistics:

- *Green logistics*, which aims to bring the environmental dimension in traditional logistics.
- *Crowd-shipping*, which encourages ordinary people to use their underexploited capacity on their cars, bikes, buses and planes to carry parcels for other people on their route.

The main goal is to provide innovative quantitative techniques to efficiently manage the “green” transportation systems, hence we proposed several variants of the Vehicle Routing Problem (VRP) by considering new perspectives. The first part of this dissertation is devoted to the *Green logistics*. In order to reduce the negative externalities, routing models and procedures have to consider sustainable factors and offer new transport strategies and solutions. One possible approach is to minimize the polluting emissions by including the emission costs into the objective function. A different approach is to use alternative fuel vehicles (AFVs), especially electric vehicles (EVs), instead of the conventional ones. In recent years several companies have started using EVs as a result of governmental incentives. While EVs do not produce CO_2 emissions and are more silent than the conventional vehicles, they are constrained by the low autonomy of their battery, the limited number of public charging stations (CSs) and long charging times. At first we have provided a brief overview on the main contributions related to the green-vehicle routing problem (G-VRP).

Then, we modeled and solved two green VRP (G-VRP) variants by incorporating sustainability goals. We considered a mixed fleet of vehicles, composed of capacitated EVs and conventional diesel vehicles. We assumed that partial battery recharges for each electrical vehicle are allowed at any available recharging station. We considered also some realistic issues related to the life span of the battery. Indeed, the full recharges can damage the battery and the last 10% of recharge requires considerable time. Thus, we also need to constrain the state of charge of the battery. Combining these elements makes the problem different from the other contributions and interesting from a point of view of the realistic applications. In particular in the first model we considered a limitation on polluting emissions for conventional vehicles. We assumed that the calculation of CO_2 emissions depends on two factors: the type of vehicle and the type and quantity of fuel consumed. The EVs energy consumption was assumed to be proportional to the distance traveled. Since real-life energy consumption is not a linear function of traveled distance, we proposed a second model by incorporating realistic energy consumption models of ECVs and conventional vehicles that take into account vehicle speed, gradient and cargo load.

The second part of the dissertation is devoted to the *Crowd-shipping*. In the last years the growing importance of shorter delivery lead times has led the companies to create innovative solutions to organize the last-mile and same-day delivery. In this context, the "sharing economy" has attracted a great deal of interest. Crowd-sourcing is strictly related with the concept of "sharing economy", and allows activities that usual are performed by a company to be outsourced to a large pool of individuals. We studied a variant of the VRP with Time Windows in which the crowd-shipping is considered. We supposed that the transportation company can make the deliveries by using its own fleet composed of capacitated vehicles and also some occasional drivers (ODs). We considered two different scenarios, in the first one multiple deliveries were allowed for each occasional driver, in the second one we introduced the split and delivery policy. We validated the two mathematical models by considering several realistic scenarios. The results have shown that the transportation company can achieve important advantages by employing the occasional drivers, which become more significant if multiple delivery and the split delivery policy are both considered. Then, we proposed a hight performing heuristic for the VRP with ODs and multiple deliveries.