A beautiful fleet: optimal repositioning in e-scooter sharing systems for urban decorum

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Electric scooters (e-scooters) have recently become a common and familiar sight in major cities around the world. Their success can be attributed to many attractive features that they offer, such as low buying price, easiness of driving and parking and low cost of maintenance. Moreover, being electrical, they represent a sustainable alternative to fossil fuel cars and may effectively contribute to reduce pollution and traffic congestion (e.g., Asdrubali et al. 2018).

In recent years, an increasing number of e-scooter-sharing companies has appeared around the world. A typical company distributes a shared fleet of e-scooters in a city and the vehicles can be easily rented through a smartphone application, paying a per minute fee. However, a major issue that has soon become apparent is that a consistent part of the users is prone to park the e-scooters without caring about the rules of the road, abandoning them in locations and positions that greatly reduce urban decorum and may interfere with pedestrians and other vehicles (see Fig. 1a). Many local governments have thus started to take actions, such as bans and fines, against e-scooter sharing companies for bad parking made by their users (see e.g., CBC 2019).

In order to cope with the issue of bad parking and to not compromise acceptance of e-scooters by city residents, some sharing companies have begun to include correcting the position of wrongly parked scooters as an important part of their operations.

In this work, we address the problem of optimally managing the actions of a set of agents who are hired by a sharing company expressly for repositioning e-scooters in order to guarantee urban decorum. We call these agents beautificators, since their fundamental task is to reposition scooters over short distances (even just a few meters), so to fix inappropriate and disordered parking made by users (see Fig. 1b). We stress that such repositioning must not be confounded with traditional relocation made in vehicle-sharing systems to rebalance fleets in the service area: rebalancing is made over medium and long city-distances and is primarily aimed at guaranteeing a balanced distribution of vehicles in the service area, better satisfying the demand and increasing the overall profit (e.g., Jorge et al. 2014).

To the best of our knowledge, such optimization problem has not yet been considered in literature and we propose to model it by Integer Linear Programming and solve it by means of a matheuristic, since its solution can be challenging even for a state-of-the-art commercial optimization solver. Our new model is inspired by and based on discussions that we had with professionals from a major European e-scooter sharing company.

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More in detail, we consider a sharing company that manages a fleet of e-scooters with non-swappable batteries and that has at disposal a set of beautificators that move across the service area to correct wrong parking of scooters, pursuing urban decorum. The work of the beautificators is planned over a time horizon that is subdivided into a set of equal time slots, whereas the target area is decomposed into a grid of sufficiently small elementary areas, called *zones*. Each zone contains an *hotspot*, namely a location where parked e-scooters are more likely to be rented (for example because they are closer to important landmarks, such as a subway station or a commercial center).

At the beginning of the time horizon, each beautificator starts in one of the zones and may execute three fundamental actions: 1) “beautifying” the parking of one e-scooter in the zone where he/she is located, putting the e-scooter in a different position (e.g., if the e-scooter has fallen on its side, it is put into vertical position, while if it has been left in a position of the curb that interferes with pedestrian walk, it is moved to the side of the curb); 2) repositioning an e-scooter to the hotspot of the zone; 3) moving to another zone to continue there his/her beautifying work.

Each action requires a number of time slots to be executed and is associated with a monetary value that jointly takes into account the cost and benefits of the action (in particular that of parking in line with urban decorum). The objective is to schedule the actions of the beautificators over the time horizon maximizing the total monetary value.

In order to model this optimization problem, we rely on a multiperiod graph including one node for each zone-time slot couple and where arcs between nodes represent actions that can be executed by the beautificators. The execution of actions is mathematically represented by an *unsplittable multicommodity flow model*, in which boolean flow variables model whether a beautificator does or does not execute an action and flow conservations constraints guarantee coherence of actions over space and time. Additional constraints are included to model hotspot capacity and limitations that beautificators have on moving between zones.

Since the resulting model can prove challenging even for a state-of-the-art commercial optimization solver, we propose to solve it by a *matheuristic* that combines a variable fixing procedure with an exact large neighborhood search, inspired by principles discussed in (D’Andreagiovanni et al., 2015). Computational tests on realistic instances defined in collaboration with professionals of a major e-scooter sharing company are reported and discussed, showing a remarkable performance of our modelling and algorithmic approach.

**References**


