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SHORT SUMMARY

Electric scooter (e-scooter) sharing has recently known a wide success around the world, thanks to its ease of use and parking. However, it soon became apparent that many of its users tend to park without caring about road rules, abandoning e-scooters in locations and positions that compromise urban decorum and interfere with pedestrians. Many municipalities have thus taken actions, such as bans and fines, against e-scooter sharing companies.

In this work, we address the problem of optimally managing the actions of a set of agents hired by a sharing company expressly for repositioning e-scooters 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. Specifically, we propose a new Integer Linear Programming model for representing the problem of jointly scheduling and choosing the actions operated overnight by beautificators and relocators (for fleet balancing) in a service area. We also propose a matheuristic for its solution (a genetic algorithm combined with exact optimization-based neighborhood searches). Computational tests on realistic instances show that our new optimization approach can return solutions of higher quality than a state-of-the-art solver.

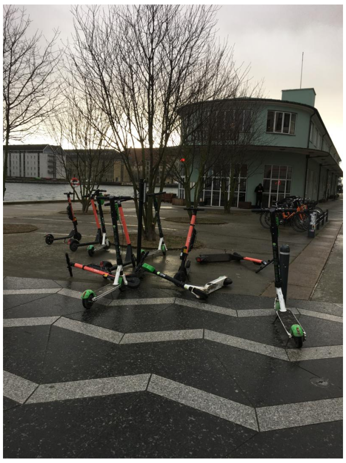
Keywords: E-scooters; Mathematical Optimization; Micromobility; Shared Mobility; Urban Decorum.

1 Introduction

In recent years, Shared Mobility (SharedMob), namely transportation services that are shared among users like car-sharing and ride-sharing, has widely spread all around the world (see (Soares Machado, De Salles Hue, Tobal Berssaneti, & Quintanilha, 2018) for an overview). SharedMob allows users to rent a vehicle for short period of times (even a few minutes) using a smartphone application and paying a per-minute fee (Weikl & Bogenberger, 2013).

It is now widely accepted that vehicle sharing has a remarkable positive impact on the quality of life in cities, contributing to reduce the dependence upon privately owned vehicles and thus helping to contain road congestion and traffic pollution. Some studies have attempted at evaluating more precisely the impact of sharing. For example, (Martin & Shaheen, 2011) indicated that the diffusion of carsharing in North America has induced a reduction from 0.47 to 0.24 in the average number of vehicles that a family owns and that, on average, each shared car has substituted from 9 to 12 private cars. Another major advantage of sharing services is that they contribute to the internalization of road transportation costs, since they support the passage from privately-owned cars to *mobility as a service*, based on the concept of *pay-as-you-go*.

Besides more traditional vehicle-sharing services that employ bikes and cars, electric scooters (e-scooters) have recently attracted a lot of attention and have become a common sight in the



(a) Chaotically parked e-scooters

(b) E-scooters repositioned by a beautificator

Figure 1: Parking situation before and after the intervention of a beautificator

landscape of cities. The success of e-scooters can be traced back to many attractive features that they possess, such as contained buying price, low cost of maintenance and ease of driving. Thanks to the fact of being electric, they are also appreciated as a practical and sustainable alternative to cars with fossil fuel for moving in urban scenarios.

Another major advantage offered by e-scooters is their easiness of parking: they can be parked practically everywhere. Such feature is very attractive to users, since they do not need to spend time and money for looking a free parking slot as in car-sharing (see the discussion in (Carrese, D'Andreagiovanni, Giacchetti, Nardin, & Zamberlan, 2020)). However, it has become a curse for municipalities that have faced a dramatic spread of wild parking: a very consistent part of users tend to park without caring about the rules of the road, leaving scooters in locations and positions that compromise urban decorum and create troubles for pedestrians and other vehicles (see Figure 1a (Gozal, 2020)). This has induced municipalities to take serious actions against e-scooter sharing companies, inflicting bans and fines for bad parking (see e.g., (CBC News, 2019; CNN, 2019)).

With the aim of tackling bad parking and preserve public acceptance of e-scooters, some sharing companies have started to include personnel that has the task of correcting the position of wrongly parked scooters. Our original work addresses the question of managing such personnel, in particular considering an optimization problem that has been identified with professionals of a major e-scooter sharing company.

Specifically, we address the problem of optimally managing the actions of a set of agents of a sharing company who have the task of 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. We emphasize that such repositioning is different from 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., (Boyaci, Zografos, & Geroliminis, 2017; Jorge, Correia, & Barnhart, 2014)).

In particular, we consider the problem of jointly optimally managing the actions of a group of beautificators and traditional relocators operating overnight for both improving the decorum of parking and rebalancing the fleet. To the best of our knowledge, the problem identified above, including beautification, has never been addressed in literature. Specifically, our original contributions are:

- we propose an Integer Linear Programming model for mathematically representing the problem of jointly scheduling and choosing the actions operated by beautificators and relocators in a service area over a night period;
- since the model can prove challenging to solve even for a state-of-the-art optimization solver, we propose a new matheuristic for its solution (in particular, we propose to combine a genetic algorithm with large variable neighborhood searches based on exact mathematical

programming techniques);

- we report results of computational tests assessing the performance of our new model and algorithm on realistic e-scooter sharing instances, defined in collaboration with professionals of the sector.

2 Mathematical Optimization Approach

We consider the problem of a sharing company that manages a fleet of e-scooters with non-swappable batteries and that has at disposal a set of beautificators and a set of relocators who have the task of moving across the service area to correct wrong parking of scooters, pursuing urban decorum, and rebalancing the distribution of the fleet. The work of both types of agents is planned over a night 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 (zones). Each zone contains one *hotspot*, i.e. a location where it is more probable that scooters will be rented (e.g., in front of a subway station). A subset of hotspots is equipped with charging racks where scooters can be parked and recharged.

At the beginning of the time horizon, each agent (beautificator or relocator) starts in one of the zones and may select an action to do from a set of feasible ones. The feasible actions of a beutificator are:

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 interfere 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.

The feasible actions of a relocator are:

1. relocating one scooter to another zone (in its hotspot or another location);
2. relocating an e-scooter and put it under charge in a hotspot equipped with charging rack;
3. moving to another zone to continue there his/her relocation 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 and relocators. The execution of actions is mathematically represented by an *unsplittable multicommodity flow model*, in which boolean flow variables model whether an agent 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 and charging rack capacity and limitations that beautificators and relocators 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 genetic algorithm with solution generation and improvement phases based on the execution of large *exact* variable neighborhood searches. The rationale at the basis of exact searches is that, while a state-of-the-art solver may find big difficulties in solving a full problem, it may instead be able to effectively and efficiently solve suitable subproblems (see e.g., (Blum, Puchinger, Raidl, & Roli., 2020; D'Andreagiovanni, Krolikowski, & Pulaj, 2015)).

Computational tests on realistic instances defined in collaboration with professionals of a major e-scooter sharing company are reported and discussed, showing that our new model and algorithm can return solutions of higher quality than a state-of-the-art solver.

References

Blum, C., Puchinger, J., Raidl, G., & Roli., A. (2011). Hybrid metaheuristics in combinatorial optimization: a survey. *Applied Soft Computing*, *11*(6), 4135-4151.

Boyaci, B., Zografos, K. G., & Geroliminis, N. (2017). An integrated optimization-simulation framework for vehicle and personnel relocations of electric carsharing systems with reservations. *Transportation Research Part B: Methodological*, *95*, 214 - 237.

Carrese, S., D'Andreagiovanni, F., Giacchetti, T., Nardin, A., & Zamberlan, L. (2020). An optimization model for renting public parking slots to carsharing services. *To appear in Transportation Research Procedia.*

CBC News. (2019). Montreal to fine lime, jump and their users for bad parking of e-scooters and e-bikes. *https://www.cbc.ca/news/canada/montreal/city-to-start-fining-lime-and-jump-for-bad-parking-1.5282300*.

CNN. (2019). E-scooters suddenly appeared everywhere, but now they're riding into serious trouble. *https://edition.cnn.com/travel/article/electric-scooter-bans-world/index.html*.

D'Andreagiovanni, F., Krolikowski, J., & Pulaj, J. (2015). A fast hybrid primal heuristic for multiband robust capacitated network design with multiple time periods. *Applied Soft Computing*, *26*, 497-507.

Gozal, M. (2020). Linkedin post. *LinkedIn*.

Jorge, D., Correia, G., & Barnhart, C. (2014). Comparing optimal relocation operations with simulated relocation policies in one-way carsharing systems. *IEEE Transactions on Intelligent Transportation Systems*, *37*, 971-982.

Martin, E., & Shaheen, S. (2011). Greenhouse gas emission impacts of carsharing in north america. *IEEE Transactions on Intelligent Transportation Systems*, *12*(4), 1074-1086.

Soares Machado, C. A., De Salles Hue, N. P. M., Tobal Berssaneti, F., & Quintanilha, J. A. (2018). An overview of shared mobility. *Sustainability*, *10*(12).

Weikl, S., & Bogenberger, K. (2013). Relocation strategies and algorithms for free-floating car sharing systems. *IEEE Intelligent Transportation Systems Magazine*, *5*(4), 100-111.