Dipartimento di Ingegneria
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ROMA TRE UNIVERSITÀ DEGLI STUDI

New regulatory and optimization approaches to smart vehicle sharing services

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Smart Mobility

A Smart Mobility System (SMS) is a strongly ICT-supported Transport System that enables a continuous connection between system administrators, customers/users and mobile and fixed infrastructures.

An SMS represents a key building block for offering innovative trustable and sustainable ways to move in urban and extra-urban scenarios, contributing to realize a smart city.

Ph.D. Thesis – main objectives

- Survey of regulations (local, national and international, in particular EU) for smart mobility systems, with special focus on vehicle sharing systems.
- Definition of recommendations for improving the regulation, in order to favour the diffusion and penetration of smart mobility systems.
- Definition of new optimization models and algorithms for **vehicle sharing systems** and services. In particular: 1) vehicle sharing parking slot optimization; 2) vehicle sharing management optimization (e.g., reservation, relocation and tariff definition)

Vehicle sharing

An SMS that allows a user to rent a vehicle (e.g., car, e-scooter, motorbike) for short periods of time (even a few minutes) paying a per-minute fee.

Major benefits for the users:

- **Cost efficiency** (fuel, insurance, maintenance included)
- **Avoidance** of costly and non-sustainable burden of owning a personal car in a city
- **Multiple vehicles at disposal 24/7** within walking distance through easy smartphone applications

Benefits for the collectivity:

- **reduces the number of circulating vehicles**
- helps to **decrease traffic, fuel consumption and CO2 emissions**
- supports the passage from privately-owned vehicles to mobility-as-a-service, based on the concept of pay-as-you-go

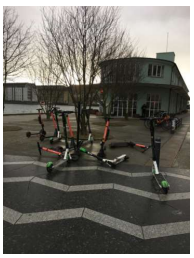
The issue of wild parking in e-scooter sharing

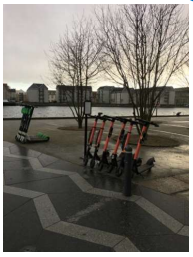
Parking an e-scooter at the end of the rent is in principle easy and fast, BUT **many users park without care** and wild parking has become a major source of issues.

Local governments have thus applied **bans, fines and severe restrictions** that have severely hit e-scooter sharing services.

Introducing the beautificators

- E-scooter companies have started to consider the possibility of including the correction of bad parking among their operations.
- Inspired by this, we introduce the figure of the **BEAUTIFICATORS**, namely agents specifically hired for correcting bad parking of users and guarantee urban decorum, repositioning e-scooters over short distances
- **Beautificators must not be confused with relocators**, who reposition shared vehicles over medium/long city distances for rebalancing the fleet distribution and better satisfy user demand





Optimal beautification in e-scooter sharing

We consider the problem of an e-scooter sharing company that must **optimally plan the actions of a group of beautificators**, to maximize a profit function while guaranteeing urban decorum by beautifying its e-scooters - 4 types of feasible actions: i) beautify; ii) bring-to-hotspot; iii) wait; iv) change zone.

$$\max \sum_{a\in A}\sum_{b\in B} \pi_a \cdot x_a^b$$

$$\sum_{a\in\delta^{FW}(z,0)} x_a^b = \begin{cases} 1 & \text{if } z = z_0(b) \\ 0 & \text{if } z \neq z_0(b) \end{cases} \qquad \forall z \in Z, b \in B$$

$$\sum_{a\in\delta^{FW}_{beau}(z,t)} x_a^b = \sum_{a\in\delta^{FW}_{beau}(z,t)} x_a^b \qquad \forall z \in Z, t \in T : 0 < t < t^{\max}, b \in B$$

$$\sum_{b\in B} x_a^b \le n_z^{\text{OUT}} \quad - \sum_{b\in B} \sum_{a=[(z,\bar{t}),(z,\bar{t}+m^{\text{HOT}})]\in A^{\text{HOT}}:\ \bar{t}=z\,\wedge\,\bar{t}<t} x_a^b \qquad \forall a = [(z,t),(z,t+m^{\text{HOT}})] \in A^{\text{HOT}}$$

$$\sum_{b\in B} x_a^b \le n_z \quad - \sum_{b\in B} \sum_{a=[(z,\bar{t}),(z,\bar{t}+m^{\text{HOT}})]\in A^{\text{HOT}}:\ \bar{t}=z\,\wedge\,\bar{t}<t} x_a^b \quad - \sum_{b\in B} \sum_{a=[(z,\bar{t}),(z,\bar{t}+m^{\text{BEAU}})]\in A^{\text{BEAU}}:\ \bar{t}=z\,\wedge\,\bar{t}<t} x_a^b \qquad \forall a = [(z,t),(z,t+m^{\text{BEAU}})] \in A^{\text{BEAU}}$$

MULTICOMMODITY FLOW MODEL ON A SPACE-TIME GRAPH WITH BINARY FLOW VARIABLES MODELING WHETHER A BEAUTIFICATOR EXECUTES AN ACTION

Computational results

- Model solved by a new MatHeuristic (MH) using **realistic data** from the city of Rome (30 zones, 5 beautificators, 75 e-scooters, time horizon of 6 hours decomposed into times slots of 10 mins), defined in collaboration with e-scooter sharing professionals

ID	v^* (CPLEX)	v^* (MH-EScooter)	$\Delta v^*\%$
I1	313	376	20.12
I2	347	409	17.86
I3	352	386	9.65
I4	406	474	16.74
I5	392	438	11.73
I6	424	467	10.14
I7	403	462	14.64
I8	397	451	13.60
I9	375	419	11.73
I10	361	394	9.14

- The problem proves hard to solve for the optimization software CPLEX
- The best feasible solutions found by MH grant higher profit (v^* in EUR) than those found by the software CPLEX within the time limit (about 14% on average, 20% in the best case)
- MH also identifies the best solutions in less time than CPLEX (about 32% less time on average)

Ongoing and Future Work

- **Extension of the model, including additional planning elements (relocation)**
- Using the results of the beautification concept and optimization approach as basis to **propose modifications and improvements of the regulation of e-scooter parking**
- Optimization of vehicle sharing operations (reservation, relocation, charging) with the aim of including **dynamic service prices**

Honours and Selected Scientific Publications

1) **Honorable Mention, 2019 COTA International Symposium on Emerging Trends in Transportation (ISETT)**
2) S. Carrese, F. D'Andreagiovanni, T. Giacchetti, A. Nardin, L. Zamberlan, "An optimization model for renting public parking slots to carsharing services", **Transportation Research Procedia (Elsevier) 2020**
3) T. Giacchetti, A. Nardin, L. Zamberlan, S. Carrese, F. D'Andreagiovanni, "A Binary Linear Programming model for optimal parking slot management of urban carsharing services", **Proceedings of 2019 COTA-ISETT**
4) S. Carrese, F. D'Andreagiovanni, T. Giacchetti, A. Nardin, L. Zamberlan, "Optimal rental and configuration of reserved parking for carsharing by Integer Linear Programming and Ant Colony Optimization", **Advances in Transportation Studies, 2019**
5) S. Carrese, F. D'Andreagiovanni, T. Giacchetti, A. Nardin, L. Zamberlan, "An optimization model and genetic-based matheuristic for parking slot rent optimization to carsharing companies", **Research in Transportation Economics (Elsevier) 2020**
6) S. Carrese, F. D'Andreagiovanni, T. Giacchetti, A. Nardin, L. Zamberlan, "A beautiful fleet: optimal repositioning in e-scooter sharing systems for urban decorum ", **Transportation Research Procedia (Elsevier) 2020**
7) S. Carrese, F. D'Andreagiovanni, T. Giacchetti, A. Nardin, L. Zamberlan, "Night makes you beautiful: an optimization approach to overnight joint beautification and relocation in e-scooter sharing", **Proceedings of MFTS 2020**

- **Talk** for presenting the paper "A beautiful fleet: optimal repositioning in e-scooter sharing systems for urban decorum" at the international conference **EWGT 2020 (23rd Conference of the EURO Working Group on Transportation)**