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Data-Driven Optimization for Transportation Logistics and Smart Mobility Applications

We live in an era of major societal and technological changes. Transportation de-carbonization and postindustrial demographic trends, such as massive migrations and an aging society, generate new challenges for cities, making the efficient and sustainable management of services and resources more necessary than ever. Cities must evolve, transform, and become smart to cope with these realities. According to the literature, a city can be referred to as smart "when investments in human and social capital and traditional (transportation) and modern [information and communications technology (ICT)] communication infrastructure fuel sustainable economic growth and high quality of life, with a wise management of natural resources, through participatory government" [1]. A smart city, hence, can be understood as responding to the challenges referred to here, propelled by opportunities that arise from societal digitalization and the evolution and progress of ICT.

Ubiquitous sensing and actuation devices do not make a city smart by themselves; it is, rather, a matter of a city's structure and dynamics, the ability of the technology to improve citizens' wealth and quality of life, and society's acceptance. Therefore, the core challenge for smart cities, and smart mobility, in particular, is twofold: first, to provide access to all traditional services in the context of rising population concentrations and, second, to make urban areas more sustainable ecosystems, taking advantage of the current redefinition of cities and the context of technological development, which translates into greener and more efficient mobility.

Indeed, a central service that affects many areas (economic development, access to health and education, and so on) is mobility. Concrete benefits can be observed, for instance, in public transportation. More accurate demand profiling by virtue of, e.g., crowd-sourced sensing applications (smart apps) may help service providers plan optimal routes and schedules and benefit travelers through services that better meet their daily needs. Privately owned vehicles can also take advantage of a holistic smart city strategy while contributing to mobility management, for example, by sharing their daily commuting traces and obtaining, in return, more precise travel-time predictions and alternative optimal routes from cities. An important aspect in smart cities and smart mobility is its bidirectionality, as can be seen from these examples.

Regarding logistics in the business world, connections have been considerably improved during recent decades. Thanks to this, an efficient logistical network can make a huge difference for companies and relevant business operations. Consequently, due to the rapid advance of technologies, different problems related to the design of smart mobility systems and the resolution of logistical situations have arisen in the literature. This fact has given these fields clear momentum in the research community, with an emphasis on realistic problem settings, data-driven models, and advanced optimization methods.

Most forms of smart mobility share a common challenge: limited resources to be optimized. The main reason for the popularity and importance of the optimization problems that underlie resource allocation in smart mobility is, again, twofold: the social interest the problems generate and the challenges that remain unsolved in this area. On the one hand, routing problems are normally designed to deal with real-world situations related to transportation

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and logistics. This is why their efficient resolution entails social and business profit. On the other hand, most of the problems appearing in this field have a big computational complexity. For this reason, the efficient resolution of these issues persists as a major challenge.

This special section aims to disseminate the latest findings, research achievements, and ideas through the lens of data-driven optimization, with the intention of balancing theoretical research ideas and their practicability as well as industrial applicability. The special section focuses on data-driven optimization algorithms and techniques, proving their use in smart city and transportation logistics applications. It contains six articles, including relevant topics from all areas of smart cities and smart mobility, from autonomous/automated/connected vehicles to a very important issue in smart logistics: data-driven fleet management (applied to taxis, in this case).

In "From Particles to Self-Localizing Tracklets: A Multilayer Particle Filter-Based Estimation for Dynamic Grid Maps," a comprehensive study is performed to show that, in a dynamic traffic environment, autonomous vehicles can estimate the trajectories and positions of all road actors by using the innovative "self-localizing tracklet" concept. The authors claim that this "self-localizing" property facilitates more precise velocity estimation.

In a very probable mobility-as-a-service transportation context, personal transportation fleets are of the utmost importance, and their management is really challenging. In "A Sequential Clustering Method for the Taxi-Dispatching Problem Considering Traffic Dynamics," a novel approach to meet the demand for mobility with acceptable satisfaction levels is shared. The authors propose a rolling horizon scheme to dynamically optimize taxi dispatching by accounting for current traffic conditions.

Data-driven research also relates to classic niches of intelligent transportation system (ITS) investigation, such as traffic modeling. "Statistical and Nature-Inspired Modeling of Vehicle Flows by Using Finite Mixtures of Simple Circular Normal Distributions" tests a new statistical model based on the expectation–maximization (EM) algorithm against a nature-inspired methodology that employs differential evolution algorithms, using New York City (NYC) traffic data. The EM method proved better, particularly through a variant that uses random initialization to fit mixed distributions to data.

Traditional urban transportation systems are also revamped by exploiting the vast amount of data they collect. Ridership demand modeling is crucial for the optimized management of metro networks. The authors of "Modeling and Analyzing Impact Factors of Metro Station Ridership: An Approach Based on a General Estimating Equation," present a new data-driven approach to model ridership and, as a bonus, an analysis of the importance of the model factors. Taipei metro network data are used to validate the model. Among the test case results, land use for commerce, bus feeder systems, the number of days that stations have been open, and the presence of transportation hubs proved to be the most significant factors.

Mobility on demand is central to mobility as a service and is typically associated with shared autonomous vehicles (SAVs). The most challenging problems related to such an approach concern how to 1) assign vehicles/rides to meet demand and 2) strategically distribute parked SAVs. In "Shared Autonomous Mobility on Demand: A Learning-Based Approach and Its Performance in the Presence of Traffic Congestion," the authors use the NYC taxi data set to propose and validate a novel shared autonomous mobility-on-demand architecture. This architecture is simulated through Simulation of Urban Mobility, a versatile open source simulation platform. One of the key elements in this work is that the methodology takes congestion into account, in contrast to most of the existing literature on this topic. The authors claim to achieve very little service deterioration in congested scenarios.

Mobility-on-demand services must be planned and widely used in smart cities. Thus, clever technical solutions need to be devised to provide quality mobility services. But when it comes down to planning, such a complex operation for real-world deployment should also consider common hassles, such as vehicle breakdowns, a fact that connects to the unquestioned need to endow these systems with robustness against eventualities. This precise problem is tackled to minimize the operational costs of disruptions in "Disruption Management for Dial-A-Ride Systems." The authors report that their proposed methodology produced a 59% reduction of the fleet idle time during normal operation and 15% when there are disruptions.

We believe that technological advances such as the ones reported in this special section will reveal the need to go beyond what we have known, so far, as "smart mobility and logistics." New advances during the years to come will not only improve the efficiency and quality of these core domains of smart cities but guarantee robustness, scalability, and adaptability to changes when advanced mobility systems are deployed in dynamic urban ecosystems. All in all, it is a matter of making plausible and valuable decisions based on data-driven technological advances in the ITS domain, in other words, making ITS systems actionable [2].

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References

[1] A. Caragliu, C. Del Bo, and P. Nijkamp, "Smart cities in Europe," Faculty of Economics, Business Administration and Econometrics, VU Univ., Amsterdam, The Netherlands, Series Research Memoranda 0048, 2009.

[2] I. Lana, J. J. Sanchez-Medina, E. I. Vlahogianni, and J. Del Ser, "From data to actions in intelligent transportation systems: A prescription of functional requirements for model actionability," 2020, arXiv: 2002.02210.

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