Editorial

Toward Sustainability: Bike-Sharing Systems Design, Simulation and Management

Leonardo Caggiani [1,*] **and Rosalia Camporeale** [2]

1   Department of Civil, Environmental, Land, Building Engineering and Chemistry,
    Polytechnic University of Bari, Via Edoardo Orabona, 4, 70125 Bari, Italy
2   Division of Transport and Roads, Department of Technology and Society, Lund University, P.O. Box 118,
    22100 Lund, Sweden; rosalia.camporeale@tfh.lth.se
*   Correspondence: leonardo.caggiani@poliba.it

1. Introduction

Bike-sharing systems (BSSs) are a mobility service of public bicycles available for shared use that is becoming increasingly popular in urban contexts. These shared systems provide city users with an alternative, low-carbon, and ecologically sustainable transportation mode (especially suited for short-distance trips) that can significantly reduce traffic congestion, air pollution and noise in city centers, and supports the growth of greener urban environments.

Different issues and challenges have been discussed in previous studies with regard to these systems [1]. Among them are BSS planning and design problems, especially concerning station locations, system simulation and operation problems, such as user demand forecasting and bicycle relocation [2,3]. In this framework, new possible solutions are constantly suggested, each one with its own strengths and weaknesses. Dockless systems (also known as free-floating BSSs) have started to become popular alongside station-based ones, both in big cities and smaller urban environments [4]. At the same time, together with regular bicycles, electric/pedal-assisted bicycles are also being used [5]: in the Vélib' BSS in Paris, for example, a mixed system with both traditional and electric bicycles has recently been implemented [6].

The goal of this Special Issue is to discuss new challenges in the simulation and management problems of both traditional and innovative BSSs, to ultimately encourage the competitiveness and attractiveness of BSSs and contribute to the further promotion of sustainable mobility. We have selected thirteen papers for publication in this Special Issue. Their contributions are summarized and discussed in the following section.

2. Synopsis of the Contributions

One of the common challenges facing all BSS operators is managing the practical problem of mismatch of bike supply and user BSS demand. To maintain the quality of service to a certain level, these systems need bicycle relocation operations to compensate for imbalances in the network.

Jia et al. (2021) (contribution 1) contribute in this sense by suggesting a new bike-sharing rebalancing problem that considers multi-energy mixed fleets and traffic restrictions (aspects mostly neglected in previous studies), using a mixed-integer programming model with the objective of minimizing the total rebalancing cost of the fleet. Their results and sensitivity analysis seem to confirm the efficacy of the algorithm to reduce the total cost associated with BSS rebalancing operations.

A different approach is proposed by Lahoorpoor et al. (2019) (contribution 2), with their bottom-up cluster-based model. They start from an investigation of spatial and temporal patterns of bike-sharing trips, aiming at discovering groups of correlated stations with an agglomerative clustering method. Intra-cluster and inter-cluster rebalancing levels

are considered, and relocation tours are optimized using a single objective genetic algorithm that minimizes the tour length significantly, which ultimately corresponds to a direct cost to the operator and indirect cost to the sustainability of BSSs.

Another crucial issue not often discussed concerns the disorderly parking of free-floating shared bikes. In their study, Jiang et al. (2019) (contribution 3) try to collect, as comprehensively as possible, the causes of such parking behavior through a two-phase questionnaire survey followed by factor analysis. Their investigation, carried out in China (where the problem is particularly acute), aims at facilitating decision-making by governments and enterprises for reference.

Several studies have already attempted to explore the factors that may affect the willingness to use BSS: individual socio-demographic characteristics (gender, age, occupation, education level, monthly income, household bicycle ownership, etc.), individual travel patterns (trip mode, travel time, trip purpose, etc.), transportation infrastructure, land use and built environment characteristics, bike-sharing facilities, and environmental conditions. Different angles and perspectives are presented in the papers collected within this Special Issue.

For instance, the stated preference survey designed and conducted by Politis et al. (2020) (contribution 4) targets car and bus users as well as pedestrians. The results highlight a distinctive set of factors and patterns: the choice of preferred transport mode is most sensitive to travel time and cost of the competitive travel options. According to their findings from Thessaloniki, Greece, BSS seems to be a more attractive option for certain socio-demographic groups and seems to mainly attract bus users and pedestrians rather than car users.

When looking at the infrastructure, the provision of a connected bikeway network has been proven one of the main measures to motivate cycling, since it is directly connected to cyclists' safety. In this regard, Shui and Chan (2019) (contribution 5) propose a novel bikeway design problem that combines a genetic algorithm and an elimination heuristic, and that aims at covering all demand sources and minimizing the total travel time of all cyclists under budget constraints. Their model, tested in two Hong Kong new towns, is not only applicable to new system designs but can also capture the existence of built bikeways and bike stations for system expansion.

Wu and Chen (2019) (contribution 6) support improvement of the night visibility of cyclists by evaluating the differences between shared and private bikes with five types of visibility aids. Their goal is to help policymakers incorporate suitable visibility aids within bike-sharing programs, enhancing the overall traffic safety conditions.

It is also of great importance to understand the motivations and barriers underlying the usage of shared bicycles. The study by Xu et al. (2020) (contribution 7) focuses on free-floating BSSs, adopting an extended theory of planned behavior (TPB) to examine psychological determinants of intention and actual behavior of users. The results, based on an online survey in Beijing, show important implications for planners and lead to several suggestions proposed to support the policymaking of the system.

More specifically, Xiao and Wang (2020) (contribution 8) target as research object of their study the brand choice of bike-sharing in China (namely Hellobike, Mobike, and Ofo). Using a conditional Logic model calibrated on data from an online questionnaire survey, they explore the influence of socio-economic attributes of cyclists and their subjective evaluations, providing a basis for traffic management departments to quantitatively evaluate performances of bike-sharing companies, and assessing the distribution of the total volume among them.

Bardi et al. (2019) (contribution 9) focus on e-bike sharing programs for cruise tourists, an additional niche of operation for bike-sharing systems. They try to understand the major driving forces that lead to the development of these programs, and the major motivating factors for cruise tourists to participate in e-bike sharing services. An ordered probit model is specified to identify the relationship among the variables influencing e-bike sharing

usage and satisfaction of cruise tourists, and interesting interpretations are provided in terms of the relative importance of significant variables.

Most existing studies mainly discuss the relationship between BSSs and external environments, while studies from the perspective of the relationship between internal stations of BSSs are insufficient. Yao et al. (2019) (contribution 10) try to fill this gap with their research. They construct the public bicycle networks of different urban areas (based on real-time data of the Nanjing public BSS) using Gephi software. Using complex network theory and a geographic visualization method, they aim to analyze internal correlation characteristics of BSSs and better understand the station usage.

Considering the large spread of BSSs, it is crucial to gain a better comprehension of the differences between these systems, hence the search for strategies to classify and compare them. An interesting possible approach for clustering different bike-sharing systems around the world can be found in the article by Mátrai and Tóth (2020) (contribution 11). They have gathered data about existing BSSs, grouping them into four categories (public, private, mixed, and other) as the first step for further identification of their common features, which can help to find similar systems and identify problems and best practices in early stages.

Moreover, Caggiani et al. (2021) (contribution 12) suggest a method to evaluate the efficiency of BSSs based on data envelopment analysis (DEA) in order to assist the decisions regarding the performance evaluation of BSS stations. A pool of input and output variables supported by literature, reports, and BSS planning guides is considered, and application to the Malmöbybike system, in Sweden, shows how this approach can provide a reliable evaluation of BSS efficiency.

We conclude the synopsis of this Special Issue's contributions with the study by Nikitas (2019) (contribution 13), which has the ambition to reinvent the formula of long-term success for bike-sharing operations by developing policy and business lessons that will help policymakers and transport providers in establishing and managing these (and other micro-mobility) schemes more effectively. Their findings are supported by primary data from two survey-based studies in Sweden and Greece.

3. What the Future of BSS Holds

The future of bike-sharing systems is of course unknown, but some speculations are possible based on what has been observed, and what trends seem to be arising.

Technological innovations are definitely contributing to a considerable change in the way of using and owning all kinds of vehicles and having an impact on all transport systems. The idea of geofencing—that is, a virtual boundary around a predetermined area or building [7]—might represent a compromise between traditional station-based and free-floating BSSs, facilitating the benefits and alleviating the challenges associated with these systems [4,8,9]. Designated operating areas to pick up and drop off vehicles could help in overcoming some docked BSS limitations (i.e., insufficient racks or station malfunctions), retaining to a certain extent the parking flexibility provided by free-floating BSSs without hindering pedestrians and/or blocking cycle paths or traffic flows.

A larger differentiation among vehicles can be foreseen. Alongside traditional bike sharing, BSSs with alternative vehicles (mixed-fleet) can attract more users and help satisfy more necessities. One possible option is represented by BSSs using e-bikes, which are superior to conventional bicycles in the ability to traverse longer distances and reach higher speeds, and in greater ease of use, especially over hilly terrains [10]. Another option can be BSSs using traditional and cargo, or e-cargo, bikes. This type of bicycle has recently gained attention as a possible urban mode of transport, particularly for families with children, or to carry heavy shopping or goods [11,12].

The most critical key usage barrier to the future development of BSSs concerns the lack of adequate cycling infrastructure (e.g., bike lanes, cycle paths, parking racks) that, in turn, is directly related to better road safety for cyclists. Poor traffic safety and insufficient bike-friendly infrastructure are the main reasons that cause reluctance to use BSSs (contribution 13, [13,14]).

Also quite relevant is the need for strategic solutions and infrastructure investments that could help in reducing pollution on urban cycle paths. Cycling in downtown areas, especially during the commute, may expose cyclists to air pollutants harmful to human health in large quantities [15,16]. Moreover, because of their physical activity, cyclists often have much higher respiration rates than people who travel by car, and consequently inhale more air pollutants over the same time [17]. The choice of paths is very important to reduce cyclists' exposure to air pollution [18]. Longer cycling routes toward the preferred destination could sometimes significantly lower this exposure. For instance, a recent study done in Coimbra [19] has shown that a 6% increase in distance and time can reduce the exposure to particulate matter and carbon monoxide related to traffic emissions by almost one-third, without requiring any additional physical effort. Hence, it is essential to acquire proper knowledge of the parameters influencing air pollution and noise along cycling facilities to better inform the planning and design of urban bicycle networks [20].

Finally yet equally importantly, there is a need to resolve challenges related to the "new normal" after the COVID-19 pandemic. The role of sustainable transport has been, in a way, redefined, and although cycling per se seems to have had a positive surge [21], the shared use of equipment in BSSs may cause concerns. Micro-mobility systems (such as bike-sharing) can definitely provide a safe alternative transport mode, but it is important that operators expand their efforts in performing and communicating precautionary actions and policies to support community health, to maintain and promote BSSs' roles during the last stages of the pandemic and afterwards [22].

4. List of Contributions

1.　Jia, Y., Zeng, W., Xing, Y., Yang, D., Li, J. The Bike-Sharing Rebalancing Problem Considering Multi-Energy Mixed Fleets and Traffic Restrictions. *Sustainability* **2021**, *13*, 270.
2.　Lahoorpoor, B., Faroqi, H., Sadeghi-Niaraki, A., Choi S.-M. Spatial Cluster-Based Model for Static Rebalancing Bike Sharing Problem. *Sustainability* **2019**, *11*, 3205.
3.　Jiang, Q., Ou, S.-J., Wei, W. Why Shared Bikes of Free-Floating Systems Were Parked Out of Order? A Preliminary Study based on Factor Analysis. *Sustainability* **2019**, *11*, 3287.
4.　Politis, I., Fyrogenis, I., Papadopoulos, E., Nikolaidou, A., Verani, E. Shifting to Shared Wheels: Factors Affecting Dockless Bike-Sharing Choice for Short and Long Trips. *Sustainability* **2020**, *12*, 8205.
5.　Shui, C.S., Chan, W.L. Optimization of a Bikeway Network with Selective Nodes. *Sustainability* **2019**, *11*, 6531.
6.　Wu, C., Chen, D. The Difference in Night Visibility between Shared Bikes and Private Bikes during Night Cycling with Different Visibility Aids. *Sustainability* **2019**, *11*, 7035.
7.　Xu, D., Bian, Y., Shu, S. Research on the Psychological Model of Free-floating Bike-Sharing Using Behavior: A Case Study of Beijing. *Sustainability* **2020**, *12*, 2977.
8.　Xiao, G., Wang, Z. Empirical Study on Bikesharing Brand Selection in China in the Post-Sharing Era. *Sustainability* **2020**, *12*, 3125.
9.　Bardi, A., Mantecchini, L., Grasso, D., Paganelli, F., Malandri, C. Flexible Mobile Hub for E-Bike Sharing and Cruise Tourism: A Case Study. *Sustainability* **2019**, *11*, 5462.
10.　Yao, Y., Zhang, Y., Tian, L., Zhou, N., Li, Z., Wang, M. Analysis of Network Structure of Urban Bike-Sharing System: A Case Study Based on Real-Time Data of a Public Bicycle System. *Sustainability* **2019**, *11*, 5425.
11.　Mátrai, T., Tóth, J. Cluster Analysis of Public Bike Sharing Systems for Categorization. *Sustainability* **2020**, *12*, 5501.
12.　Caggiani, L., Camporeale, R., Hamidi, Z., Zhao, C. Evaluating the Efficiency of Bike-Sharing Stations with Data Envelopment Analysis. *Sustainability* **2021**, *13*, 881.
13.　Nikitas, A. How to Save Bike-Sharing: An Evidence-Based Survival Toolkit for Policy-Makers and Mobility Providers. *Sustainability* **2019**, *11*, 3206.

References

1. Ricci, M. Bike sharing: A review of evidence on impacts and processes of implementation and operation. *Res. Transp. Bus. Manag.* **2015**, *15*, 28–38. [CrossRef]
2. Caggiani, L.; Camporeale, R.; Ottomanelli, M.; Szeto, W.Y. A modeling framework for the dynamic management of free-floating bike-sharing systems. *Transp. Res. Part C Emerg. Technol.* **2018**, *87*, 159–182. [CrossRef]
3. Eren, E.; Uz, V.E. A review on bike-sharing: The factors affecting bike-sharing demand. *Sustain. Cities Soc.* **2020**, *54*, 101882. [CrossRef]
4. Chen, Z.; van Lierop, D.; Ettema, D. Dockless bike-sharing systems: What are the implications? *Transp. Rev.* **2020**, *40*, 333–353. [CrossRef]
5. Zhu, S. Optimal fleet deployment strategy: Model the effect of shared e-bikes on bike-sharing system. *J. Adv. Transp.* **2021**, *2021*, 6678637. [CrossRef]
6. Vélib'. Available online: https://en.wikipedia.org/wiki/V%C3%A9lib%27 (accessed on 26 June 2021).
7. AlFayad, F.S. Geofencing in the GCC and China: A Marketing Trend That's Not Going Away. *J. Mark. Consum. Res.* **2018**, *46*, 84–98.
8. Zhang, Y.; Lin, D.; Mi, Z. Electric fence planning for dockless bike-sharing services. *J. Clean. Prod.* **2019**, *206*, 383–393. [CrossRef]
9. Mahmoodian, V.; Zhang, Y.; Charkhgard, H. *Design of a Hybrid Rebalancing Strategy to Improve Level of Service of FreeFloating Bike Sharing Systems*; CTECH Final Report; eCommons: Cornell's Digital Repository-Cornell University Library: Ithaca, NY, USA, 2019.
10. Ghamami, M.; Shojaei, M. Introducing a Design Framework for a Multi-Modal Public Transportation System, Focusing on Mixed-Fleet Bike-Sharing Systems. *Transp. Res. Rec.* **2018**, *2672*, 103–115. [CrossRef]
11. Becker, S.; Rudolf, C. Exploring the potential of free cargo-bikesharing for sustainable mobility. *Gaia-Ecol. Perspect. Sci. Soc.* **2018**, *27*, 156–164. [CrossRef]
12. Hess, A.K.; Schubert, I. Functional perceptions, barriers, and demographics concerning e-cargo bike sharing in Switzerland. *Transp. Res. Part D Transp. Environ.* **2019**, *71*, 153–168. [CrossRef]
13. Ge, Y.; Qu, W.; Qi, H.; Cui, X.; Sun, X. Why people like using bikesharing: Factors influencing bikeshare use in a Chinese sample. *Transp. Res. Part D Transp. Environ.* **2020**, *87*, 102520. [CrossRef]
14. Podgórniak-Krzykacz, A.; Trippner-Hrabi, J. Motives and factors that determine city residents' use of public bicycles. The case of Lodz, Poland. *Case Stud. Transp. Policy* **2021**, *9*, 651–662. [CrossRef]
15. De Hartog, J.J.; Boogaard, H.; Nijland, H.; Hoek, G. Do the health benefits of cycling outweigh the risks? *Environ. Health Perspect.* **2010**, *118*, 1109–1116. [CrossRef] [PubMed]
16. Apparicio, P.; Carrier, M.; Gelb, J.; Séguin, A.M.; Kingham, S. Cyclists' exposure to air pollution and road traffic noise in central city neighbourhoods of Montreal. *J. Transp. Geogr.* **2016**, *57*, 63–69. [CrossRef]
17. Panis, L.I.; de Geus, B.; Vandenbulcke, G.; Willems, H.; Degraeuwe, B.; Bleux, N.; Mishra, V.; Thomas, I.; Meeusen, R. Exposure to particulate matter in traffic: A comparison of cyclists and car passengers. *Atmos. Environ.* **2010**, *44*, 2263–2270. [CrossRef]
18. Carreras, H.; Ehrnsperger, L.; Klemm, O.; Paas, B. Cyclists' exposure to air pollution: In situ evaluation with a cargo bike platform. *Environ. Monit. Assess.* **2020**, *192*, 470. [CrossRef]
19. Giménez-Gaydou, D.A.; dos Santos, A.C.; Mendes, G.; Frade, I.; Ribeiro, A.S. Energy consumption and pollutant exposure estimation for cyclist routes in urban areas. *Transp. Res. Part D Transp. Environ.* **2019**, *72*, 1–16. [CrossRef]
20. Minet, L.; Stokes, J.; Scott, J.; Xu, J.; Weichenthal, S.; Hatzopoulou, M. Should traffic-related air pollution and noise be considered when designing urban bicycle networks? *Transp. Res. Part D Transp. Environ.* **2018**, *65*, 736–749. [CrossRef]
21. Nikitas, A.; Tsigdinos, S.; Karolemeas, C.; Kourmpa, E.; Bakogiannis, E. Cycling in the Era of COVID-19: Lessons Learnt and Best Practice Policy Recommendations for a More Bike-Centric Future. *Sustainability* **2021**, *13*, 4620. [CrossRef]
22. Jobe, J.; Griffin, G.P. Bike share responses to COVID-19. *Transp. Res. Interdiscip. Perspect.* **2021**, *10*, 100353.