PhD Topic 8: Optimization Issues in Public Bike Sharing Systems

First Supervisor	Prof. Dr. Günther Raidl
Second Supervisor	Prof. Dr. A Min Tjoa
Primary Field	Algorithmic Modeling, Simulation, Optimization
Secondary Field	Smart Solutions
Interdisciplinary References	C2, C3, C4, E2, E4

Public self-service bike sharing systems, such as Vienna's Citybike or Paris' Velib, are highly successful models in which bicycles are left at the free disposal of users throughout major parts of the cities [2]. Users can take a bike at any time and from any station and also bring it back almost whenever and wherever they want. Such systems effectively augment public transport in major cities in a very environmental-friendly way, reducing individual traffic with motorized vehicles and also motivating people to be active and do something for their health. While such systems are booming among major cities since several years, there are still many open research questions concerning an optimal setup and maintenance. This PhD topic addresses two particular aspects: (a) the selection and sizing of additional bike stations to extend an existing system and (b) the continuously required transfers of bikes among stations in order to keep the system balanced, i.e., to have enough bikes as well as free parking slots available at any station. Especially the last aspect is crucial for the acceptance of the system by the users [9].

Diverse studies concerning the expected demands at various locations within a city in dependence of crucial factors such as the weather, day of the week, closeness to public transport stations as well as other places of interest already exist [2,8,9]. This PhD topic concentrates on algorithmic/mathematical approaches for optimizing the allocation of additional resources (stations) and the planning of the regular maintenance trips for transporting bikes among stations in order to achieve a maximally balanced state throughout each day when estimated demands are already given. Some work in this direction on simplified models already exists, see e.g. [1,3,4], but due to the complexity of these problems, there is still substantial room for improvement. According to Citybike Vienna, especially the rebalancing is currently still done by mainly following human intuition instead of seriously optimized planning. A substantial saving w.r.t. traveling costs, also reducing the related environmental impact, as well as an increased user satisfaction due to less entirely empty or full rental stations can be expected when putting more effort in finding improved planning strategies.

From an algorithmic point of view, we are faced with extended variants of resource allocation problems and capacitated split pickup and delivery vehicle routing problems, in which stochastic and dynamic/online aspects also play major roles. Based on our previous work in the domains of transportation optimization and network design, see e.g. [5,6,7], we will address these challenges primarily with mathematical programming techniques including branch-and-cut, column generation, Benders decomposition, and stochastic programming, but also with heuristic methods and hybrids thereof. Algorithmic results of this project will presumably also be highly relevant for other application domains.

References:

[1] Benchimol, M., Benchimol, P., Chappert, B., De la Taille, A., Laroche, F., Meunier, F., & Robinet, L. (2011). Balancing the Stations of a Self Service “Bike Hire” System. RAIRO - Operations Research, 45(1), 37-61.

[2] DeMaio, P. (2009). Bike-sharing: History, impacts, models of provision, and future. Journal of Public Transportation, 12(4), 41-56.

[3] Meunier, F., Wolfler Calvo, R., & Chemla, D. (2010). Bike Hiring System: Solving the Rebalancing Problem in the Static Case. Transportation Science, submitted.

[4] Raviv, T., Tzur, M., & Forma, I. A. (2011). Static Repositioning in a Bike-Sharing System: Models and Solution Approaches. Tel Aviv, Israel, submitted.

[5] Pirkwieser, S., & Raidl, G. R. (2009). A Column Generation Approach for the Periodic Vehicle Routing Problem with Time Windows. In M. G. Scutellà & others (Eds.), Proceedings of the International Network Optimization Conference 2009. Pisa, Italy.

[6] [6] Pirkwieser, S., & Raidl, G. R. (2010). Matheuristics for the Periodic Vehicle Routing Problem with Time Windows. *Proceedings of Matheuristics 2010: Third International Workshop on Model-Based Metaheuristics* (pp. 83-95). Vienna, Austria.

[7] [7] Pirkwieser, S., & Raidl, G. R. (2010). Variable Neighborhood Search Coupled with ILP-based Large Neighborhood Searches for the (Periodic) Location-Routing Problem. In M. J. Blesa & others (Eds.), *Hybrid Metaheuristics, 7th Int. Workshop, HM 2010*. LNCS Vol. 6373 pp. 174-189). Springer.

[8] [8] Vogel, P., Mattfeld, D., Böse, J., Hu, H., Jahn, C., Shi, X., Stahlbock, R., et al. (2011). Strategic and Operational Planning of Bike-Sharing Systems by Data Mining – A Case Study, *Computational Logistics*. LNCS Vol. 6971, pp. 127-141. Springer.

[9] [9] Vogel, P., Greiser, T., & Mattfeld, D. C. (2011). Understanding Bike-Sharing Systems using Data Mining: Exploring Activity Patterns. *Procedia-Social and Behavioral Sciences*, *20*, 514–523. Elsevier.