Professorship of Business Analytics and Intelligent Systems
TUM School of Management
Technical University of Munich

Staggered Routing In Autonomous Mobility-on-Demand

An *autonomous mobility-on-demand* (AMoD) system is a type of transportation system that employs a fleet of centrally controlled self-driving vehicles to provide ride-hailing services to passengers. AMoD systems are a recently emerging transportation paradigm that provides a convenient, safe, and cost-effective alternative to traditional transportation modes, such as private cars, buses, and taxis. Private companies and public transportation authorities can deploy AMoD fleets in various settings, including urban areas and suburbs, and for various purposes, such as commuting or sightseeing. The operation of such a fleet is subject to a system perspective, which leaves the task to scientists and practitioners to investigate novel mechanisms to improve the system state, e.g., by decreasing congestion or increasing vehicle utilization. One technique to achieve this is *staggered routing*, in which the AMoD central operator shifts travel requests to find passenger pick-up times. The underlying decision problem is called *staggered routing problem*, in which the operator searches for pick-up times that minimize local congestion on road links during peak hours while ensuring timely arrivals. Although AMoD systems' efficiency can benefit from carefully scheduling passengers' departure times, staggered routing can also negatively impact passenger convenience due to longer waiting times. Understanding under which conditions staggered routing can benefit transportation services is currently object of investigation. From a computational perspective, finding an optimal set of pick-up times can be challenging due to the combinatorial number of solutions, making the design of efficient real-time algorithms challenging, especially when considering large-scale fleets.

Aims and scope of the thesis
The thesis aims to develop a formulation for the *staggered routing problem* of an AMoD fleet via mathematical programming and develop suitable exact or approximate approaches to solve the problem in large-scale settings. The solution might entail decomposition techniques or the development of a meta-heuristic framework. The student will carry out the following tasks:

- Formulation of a mathematical model for staggered routing
- Development and implementation of a scalable solution approach
- Application of the introduced model and solution approach to a case study
- Discussion of operational and managerial insights

Requirements
This thesis targets students of the TUM-BWL (with a major in Supply Chain Management), Informatics, Engineering, or similar study programs. Knowledge of mathematical programming, optimization, and a general-purpose programming language (e.g., C++, Java, Python) is required. Prior participation in one of the seminars offered by the chair (i.e., Modeling Future Mobility Systems, Advanced Seminar) is recommended. The thesis should be written in English.

Related Research
- Zardini, G., Lanzetti, N., Pavone, M., & Frazzoli, E. (2021). Analysis and control of autonomous mobility-on-demand systems: A review. arXiv preprint arXiv:2106.14827.
- Rossi, F., Zhang, R., Hindy, Y., & Pavone, M. (2018). Routing autonomous vehicles in congested transportation networks: Structural properties and coordination algorithms. Autonomous Robots, 42(7), 1427-1442.
- Yang, Y., Abe, H., Baba, K. I., & Shimojo, S. (2012). Staggered flows: An application layer's way to avoid incast problem. IEEE Asia Pacific Cloud Computing Congress (APCloudCC) 64-67.

Begin: as soon as possible

Advisor: Antonio Coppola

Application: See `https://www.ot.mgt.tum.de/osm/education/master-thesis/`