Philipp Stockerl
Matr. No 107829

Chair of Business Decisions & Data Science
Prof. Dr. Marc Goerigk

Faculty of Business Administration
and Economics

Bachelor's Thesis Proposal: Static and Dynamic Vehicle Routing under Uncertainty

RESEARCH QUESTION

How can static and dynamic optimization approaches be compared in vehicle routing problems when operating under uncertain and spatially variable environmental conditions?

MOTIVATION AND BACKGROUND

During my studies, I have focused on Operations Research and Decision Analytics within both the Business Administration and Information Systems degree programs. I completed all courses previously offered by the former Chair of Prof. Dr. Alena Otto, including the bachelor seminar on uncertainty in competitive facility location, with the original intention of writing my thesis under her supervision. Following her unexpected departure from the University of Passau in early 2024 and the subsequent written notice regarding my application, I now aim to continue my thesis project in close alignment with her research area under the supervision of Prof. Dr. Marc Goerigk at the Chair of Business Decisions & Data Science.

In my seminar paper with Prof. Dr. Alena Otto on Competitive Facility Location, I studied Drezners model (*Competitive Facility: Random Utility*) and explored classical approaches such as Huff and Hotelling. In the *Practical Course: Management Science*, I implemented a *Minimum Cost Flow Problem* using Gurobi and Python, which has prepared me well to handle both the robust extension and its implementation in this thesis.

The deployment of Unmanned Aerial Vehicles (UAVs) in logistics has increased rapidly. Efficient route planning is critical for safety, energy consumption, and reliability. While static optimization techniques compute fixed routes based on predicted data, dynamic approaches allow continuous adaptation as new information becomes available. This thesis examines how both paradigms perform when confronted with uncertain or imperfect information about travel conditions, highlighting the trade-off between conservatism and adaptability in UAV routing.

CONNECTION TO BUSINESS INFORMATICS

This thesis is closely related to the field of Business Informatics, as it combines methods of Operations Research with data-driven decision support and intelligent information systems. The project focuses on the integration of optimization and adaptive planning models into digital decision-making architectures that process uncertain and spatially distributed data. By simulating real-time updates, sensor-based information flows, and autonomous decision logic, it reflects the principles of prescriptive analytics and intelligent decision support systems. Such systems are fundamental in modern business analytics, where organizations increasingly rely on algorithmic decision-making to enhance responsiveness, transparency, and operational efficiency.

The developed framework thus represents a bridge between analytical modeling and information systems design, contributing to the digital transformation of operational processes and providing methodological insights for future decision-support and business intelligence applications in dynamic environments.

METHODOLOGY AND DATA

The study compares representative static and dynamic optimization models in a controlled simulation environment. Synthetic spatial networks will be generated where edge costs are derived from Gaussian random fields that mimic environmental effects such as wind or turbulence. Two data layers will be created:

- A **blurred forecast map** representing anticipated cost patterns (e.g., weather prediction).
- A **clear actual map** representing true realized travel conditions as encountered by the vehicle.

The static model, based on the Bertsimas Sim robust optimization framework, computes a pre-planned route using the forecast data and an uncertainty budget Γ. This route is then provided as the initial path to a dynamic replanning model implemented with algorithms like D* Lite, which receives local sensor updates and may adapt the route if actual conditions differ. Instead of binary obstacles, uncertain regions will be modeled as *delay zones* that increase traversal cost without blocking connectivity.

EVALUATION DESIGN

The performance of both methods will be analyzed under varying relationships between forecast and actual conditions:

- Actual conditions are **better than expected**: robust model overcompensates; dynamic method may improve efficiency.
- Actual conditions **match the forecast**: both models expected to behave similarly.
- Actual conditions are **worse than expected**: stress-test for robustness and recovery capability.

Key metrics include total realized cost, computational time, robustness ratio (worst/nominal cost), and adaptability (number of successful replans). This setup enables a quantitative assessment of how pre-computed robustness and real-time adaptability balance efficiency and reliability in uncertain routing environments.

SELECTED REFERENCES

- Bertsimas, D., & Sim, M. (2003). *Robust discrete optimization and network flows.* Mathematical Programming, 98(1), 4971.
- Dijkstra, E. W. (1959). *A note on two problems in connexion with graphs.* Numerische Mathematik, 1(1), 269271.
- Koenig, S., & Likhachev, M. (2002). *D* Lite.* In AAAI Conference on Artificial Intelligence.