Topic Proposal for a thesis:

# Exploiting Structural Properties for Optimization

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## Background and Importance

Optimization problems are ubiquitous in modern industries, with many real-world problems being modelled as such to improve operational efficiency and decision-making. A critical aspect of solving these problems lies in leveraging the structural properties of the models to achieve better formulations and subsequently better solutions. This approach is particularly relevant in the context of public transportation planning, where timetabling can be seen as a complex optimization problem.

This project, developed in collaboration with SBB, a leading Swiss transportation company, focuses on the optimization of timetable planning through the exploitation of structural properties. Working on this real-world problem will provide the students with a rich experience, bridging the gap between theoretical knowledge and industry practice.

## Problem description

The project involves analyzing existing implementations and problems to ascertain if and how the formulation can be strengthened. Potential areas to investigate include achieving more compact lower bounds through tighter bounds and Big-M values, and identifying new constraints/cuts to accelerate the solution process. This research will enable students to contribute to an essential aspect of public transportation planning and will have a direct impact on SBB's operations.

## Approach

In this project, students will gain insights not only into technical improvements, such as runtime enhancement, but also into the structural properties of these problem classes. Both the literature and personal creativity can guide the exploration of measures and approaches for improving the formulation.

Working with SBB, students will have the opportunity to directly impact real-world operations. SBB is always interested in improving the performance of their solver, and the implementation of the project results into production is highly probable. However, students will work primarily with RouteGraphs and MILP formulations, not directly with the code. This approach allows for a structured learning process and clear deliverables.

## Research Question

The primary research question is:

- How can the exploitation of structural properties enhance the optimization process in terms of improving the formulation and accelerating the solution process?

Additional elements that the student may consider are:

- How can more compact lower bounds be achieved through tighter bounds and Big-M values?
- Can new constraints/cuts be identified to expedite the solution process?