Title : A Dynamic Multi-objective Model For Campus Timetable Scheduling

Scientific domains : *Operations Research, Data Science, Education Management*

Key-Words : University timetabling, Carpooling, multi-objective optimization, simulation, sensitivity analysis

Supervision

Supervisor (s) :

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Research Work

Abstract of the internship

This internship aims to develop a dynamic multi-objective model for optimizing timetabling schedules within a university campus so as to maximize ridesharing and carpooling between students. The model will integrate simulation and sensitivity analysis to identify optimal allocation of students to on-campus vs distance courses as well as optimal timetabling of courses/classes to minimize environmental impacts, traffic congestion, and maximize carpooling usage while respecting training quality constraints.

Internship Project

The objective of the internship is to develop a mathematical optimization model and algorithm to solve a dynamic multi-objective university timetabling problem that maximizes ridesharing between students. The model will integrate linear/nonlinear programming, simulation, and sensitivity analysis.

Scientific context

University timetabling has garnered significant attention in the field of scheduling due to its inherent complexity, encompassing various constraints that need to be addressed. Numerous existing approaches predominantly center on devising single-objective solutions, aiming to streamline the scheduling process by focusing on one dimension of optimization.

However, as the demand for more comprehensive and nuanced solutions grows, there is a discernible gap in the literature concerning dynamic multi-objective models for university timetabling. This internship endeavors to contribute to the existing body of knowledge by developing a dynamic multi-objective model that not only optimizes traditional factors like time efficiency but also incorporates emerging considerations such as environmental sustainability and transportation efficiency.

By introducing a dynamic aspect to the model, it adapts to the evolving needs and constraints of the university scheduling environment. To further contextualize this research, previous works in the domain of multi-objective optimization and timetabling can be referenced. For instance, studies by Burke et al. (2019) and Li et al. (2021) delve into multi-objective optimization techniques for timetabling, providing valuable insights that can inform the development of the proposed model. Additionally, the work of Smith and Jones (2020) on incorporating sustainability considerations in scheduling processes serves as a relevant foundation for integrating environmental concerns into the proposed model.

Internship subject

While existing works have made commendable strides, certain limitations persist within the current literature. First, many of the prevalent single-objective optimization approaches tend to oversimplify the intricate nature of the scheduling problem by focusing solely on one dimension, often neglecting the interplay between various factors. This limitation can result in suboptimal solutions that fail to address the multifaceted constraints inherent in university timetabling. Moreover, a substantial portion of the existing literature lacks a dynamic perspective, with solutions often being static and unable to adapt to evolving scheduling requirements. This limitation is particularly significant as universities experience fluctuations in student enrollments, course offerings, and faculty availability, necessitating a more responsive and adaptive approach to timetabling.

Additionally, the current body of work in university timetabling tends to underemphasize the integration of emerging considerations such as environmental sustainability and transportation efficiency. While some recent efforts touch upon these aspects, the incorporation remains limited and often lacks a comprehensive approach. Consequently, there is a need for research that systematically integrates these evolving factors into the optimization model, reflecting the increasing importance of sustainability in academic institutions. Furthermore, the majority of existing studies often employ static and predetermined sets of constraints, which may not fully capture the dynamic nature of real-world university scheduling scenarios. An enhanced model should account for uncertainties, unexpected events, and real-time changes, ensuring adaptability in the face of unforeseen challenges.

To address these limitations and advance the state-of-the-art in university timetabling, this internship seeks to develop a dynamic multi-objective model that not only surpasses the constraints of single-objective approaches but also incorporates adaptability, responsiveness, and a more comprehensive consideration of emerging factors. By doing so, this research aims to contribute significantly to the ongoing discourse and pave the way for more effective and resilient university timetabling solutions, while considering ridesharing maximization.

The intern will formulate the timetabling problem as a mixed integer linear/nonlinear program incorporating objectives like pollution reduction, carpooling usage maximization, congestion minimization and modal shift incentives. Simulation and sensitivity analysis will be used to evaluate model performance under uncertainty and identify key decision drivers. The solution approach may integrate metaheuristics or decomposition techniques

Work program

*The internship will start in the **first month** with an immersive dive into the existing body of knowledge surrounding university timetabling, and ridesharing issues. This initial phase involves an extensive literature review, delving into seminal works by prominent researchers in the field. Simultaneously, the problem space is meticulously defined, outlining the objectives and challenges associated with university timetabling.*

*The **second month** marks a pivotal transition to the hands-on phase of the internship. Here, the focus shifts to the design and implementation of a dynamic multi-objective model tailored to address the identified gaps and challenges (ie., timetabling with carpooling usage maximization).*

*Building upon this foundation, the **third month** is dedicated to the development of simulation tools and sensitivity analysis components. These components serve as crucial assets, enabling a comprehensive examination of the model's responsiveness and adaptability under various scenarios.*

*Moving into the **fourth month,** the internship takes on a more technical dimension with a focus on algorithm development and testing. Advanced optimization algorithms are explored and implemented to enhance the model's efficiency, ensuring its applicability to real-world, large-scale university scheduling instances.*

*In **the fifth month**, the spotlight turns to model validation, sensitivity analysis, and an in-depth analysis of results. This critical phase involves rigorous testing and validation against real-world data, providing valuable insights into the model's performance and limitations.*

*The conclusive **sixth month** is dedicated to synthesizing the comprehensive findings into a well-documented final report. Additionally, the intern has the opportunity to share their insights, methodologies, and outcomes with the broader academic community through a conference presentation, contributing to the ongoing discourse and advancement of knowledge in the field of university timetabling.*

Expected scientific production

A conference paper submission on the model framework and computational results. A final report detailing the full methodology, implementation, case study application and conclusions.

Context

Lab presentation

CESI LINEACT (UR 7527), Laboratory for Digital Innovation for Businesses and Learning to Support the Competitiveness of Territories, anticipates and accompanies the technological mutations of sectors and services related to industry and construction. The historical proximity of CESI with companies is a determining element for our research activities, and has led us to concentrate our efforts on applied research close to the company and in partnership with them. A human-centered approach coupled with the use of technologies, as well as territorial networking and links with training, have enabled the construction of cross-cutting research; it puts humans, their needs and their uses, at the center of its issues and addresses the technological angle through these contributions.

Its research is organized according to two interdisciplinary scientific teams and two application areas.

- Team 1 "Learning and Innovating" mainly concerns Cognitive Sciences, Social Sciences and Management Sciences, Training Techniques and those of Innovation. The main scientific objectives are the understanding of the effects of the environment, and more particularly of situations instrumented by technical objects (platforms, prototyping workshops, immersive systems...) on learning, creativity and innovation processes.
- Team 2 "Engineering and Digital Tools" mainly concerns Digital Sciences and Engineering. The main scientific objectives focus on modeling, simulation, optimization and data analysis of cyber physical systems. Research work also focuses on decision support tools and on the study of human-system interactions in particular through digital twins coupled with virtual or augmented environments.

These two teams develop and cross their research in the two application areas of the Industry of the Future and the City of the Future, supported by research platforms, mainly the one in Rouen dedicated to the Future Factory and those in Nanterre dedicated to the Future Factory and Building.

Internship organisation

Funding : MobE Research Program

Workplace : *CESI LINEACT Rouen campus*

Starting date : *January/February 2024*

Duration of the internship : *6 months*

Recruitment terms and conditions

Terms : by application and interview.

Please send your application to mbenatia@cesi.fr with the following subject:

"[Application] Title on page 1".

Your application must include :

- A detailed Curriculum-Vitae. In the event of a break in the academic curriculum, please give an explanation;
- A cover letter explaining why you wish to pursue an internship;
- MASTER 1 and 2 results (to be adapted to the level of the internship) and corresponding transcripts;
- any other documents you consider useful.

Please send all documents in a zip file entitled NAME firstname.zip.

Skills :

Scientific and technical skills :

Mathematical modeling, Python programming, Java is a plus,

Relational skills :

The ability to collaborate across scientific domains is essential. Strong communication skills and the capacity to integrate insights from operations research, computer science, environmental science, and education management will contribute to the success of the project.

Bibliography.

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