

SURVEY

A Survey of Solution Methodologies for Exam Timetabling Problems

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ABSTRACT Exam timetabling is a prominent topic in academic administration management as it ensures the effective utilization of resources and satisfies the requirements and preferences of stakeholders, which leads to a productive academic environment, contributing to the institution's overall success. Given the myriad of solution methodologies explored across diverse exam timetabling problems and constraints, both in studied benchmark datasets and real-life cases over the last decade, it is imperative to undertake a comprehensive survey. This survey paper aims to comprehensively describe the exam timetabling problem (ETP), including its variants, constraints, and benchmark dataset. We look at different methods to solve ETP problems from 2012 to 2023. These methods include mathematical optimization, heuristics, metaheuristics, hyper-heuristics, hybrid approaches, and matheuristics. Finally, we discuss the review findings and potential research directions. By doing so, we hope to facilitate a deeper understanding of ETP and offer valuable insights for future research.

INDEX TERMS Educational timetabling, exam scheduling, exam timetabling, solution methodologies.

I. INTRODUCTION

Educational timetabling represents a significant instance among challenging combinatorial optimization problems [89]. This intricate problem is conventionally classified into three principal types: school timetabling, course timetabling, and examination timetabling [1]. Each involves assigning events (e.g., meetings, exams, lectures, tutorials, classes) to limited resources (e.g., timeslots and rooms) while adhering to predefined constraints. Despite similarities, solving one problem type with a method does not guarantee success with another. Consequently, each problem type has been addressed

independently, and each instance may differ significantly in constraints and dimensions.

Exam timetabling problem (ETP) was defined by Qu et al. [2] as “assigning a set of exams into a limited number of timeslots (periods) and rooms (of certain capacity) subject to a set of constraints.” Constraints can vary in definition or weighting based on institutional requirements. The scientific community has been studying the ETP since the 1960s, with an early survey conducted by [3] focusing on practical applications of graph coloring heuristics from 1964 to 1984. Carter and Laporte [4] extended the survey by categorizing algorithms into sequential, generalized search, cluster, and constraint-based methods, while Schaerf [1] reviewed the early approaches for resolving the ETP. Most algorithms primarily addressed the basic

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timetabling problem with minimal constraints during that period.

The area of timetabling problems, including exam timetabling, has a thriving research community, with notable biannual conference series such as Practice and Theory of Automated Timetabling (PATAT) dedicated to timetabling practices and their applications. Exam timetabling constantly evolves, leading to rapid developments in theory and practice. With more standardized benchmark datasets, researchers are exploring ways to place the timetabling problem in a real-world context. Some studies focus on the optimality gap when solving benchmark instances, while others prioritize the time to find a feasible solution.

Many studies have investigated educational timetabling; however, the breadth of the field restricts each to addressing specific problem subsets. In 2008, Lewis [70] focused his study on metaheuristic techniques, while Pillay [72] focused on hyper-heuristics within educational timetabling in 2014. In 2020, Bashab et al. [73] specifically concentrated on university timetabling using metaheuristic techniques. In 2022, Ceschia et al. [74] focused on benchmarks and state-of-the-art results in educational timetabling. Numerous survey papers in educational timetabling have delved into specific subdomains, such as course timetabling [87] and school timetabling [88], each with its associated methods [83], [84], [85], [86], respectively.

For dedicated surveys focusing on exam timetabling, Qu et al. [2] conducted a comprehensive study from 1995 to 2008, discussing key research achievements and trends in exam timetabling, encompassing algorithmic strategies, benchmark datasets, and emerging challenges. The survey by Bashar et al. in 2019 [5] exclusively concentrates on one formulation of ETP, namely the Uncapacitated ETP. Notably, the need for dedicated surveys addressing the exam timetabling problem is even more pronounced when compared to other educational timetabling subdomains. This scarcity encompasses the analysis of benchmark datasets or specific methods and the investigation of real-world problem constraints and requirements. Examining existing literature is crucial to discern gaps in exam timetabling research, considering substantial advancements in problem understanding and solution methodologies over the past decade.

This survey is essential for bridging the gap between benchmark datasets introduced over a decade ago and recent real-world cases, providing valuable insights to researchers, educators, and policymakers to navigate the evolving landscape of exam timetabling challenges. The contributions of this survey paper are:

- We present an overview of the terminologies, problem descriptions, variants, and constraints related to the ETP. The review outlines the commonly used ETP benchmark datasets, detailing their respective characteristics and state-of-the-art methods.
- We provide an up-to-date overview of recent solution methodologies employed in ETPs, encompassing both

benchmark and real-world ETPs from 2012 to 2023. Furthermore, we have structured the article based on the methods and techniques in chronological order, aiding readers in comprehending the methodology timeline in the field.

- We categorize solution methods into six categories: mathematical optimization, heuristics, matheuristics, metaheuristics, hybrid approaches, and hyper-heuristics. The tables and figures in this article categorize these methods, facilitating researchers in selecting categories of interest for further study.
- We discuss the classification of the recent methodologies used in the ETP field and propose future research directions.

The remainder of the paper is structured as follows: Section II outlines the scope of the reviewed paper. Section III defines the problem variants and constraints. Section IV classifies and offers an overview of solution methodologies for ETPs. The categorization of these solution methodologies is discussed in Section V. Section VI highlights trends in benchmark ETP. Section VII discusses potential future directions. The paper concludes with Section VIII.

II. SURVEY SCOPE

We opted to initiate the search period in 2012 since it marked the commencement of widespread publications on exam timetabling problems, employing various solution methodologies. Bibliographic information was obtained from the Science Citation Index Expanded (SCIE) and Social Science Citation Index (SSCI) within the Web of Science Core Collection by Clarivate Analytics. The search involved looking for phrases related to exam timetabling in the topic field from 2012 to 2023 in the SSCI and SCIE databases. Additionally, further refinement of publications was carried out by selecting articles that prominently featured the search keywords in their front page elements, including the article title, abstract, author keywords, and year published. The search terms and research strategy utilized for exam timetabling were elaborated upon, encompassing the following criteria:

Article title: “exam timetabling” or “examination timetabling” or “university timetabling” or “exam timetabling problem” or “exam scheduling” or “examination scheduling” or

Abstract: “exam timetabling” or “examination timetabling” or

Keywords: “exam timetabling” or “examination timetabling” and

Year: “2012-2023”

The search results (last accessed: January 9, 2024) resulted in 1,955 publications meeting these criteria, which were subsequently retrieved for further analysis. Apart from that, publications from the journal OPSEARCH are also included. After excluding specific publication types such as dissertations, conference proceedings, surveys, reviews, book chapters, partial exam-related studies, and those with fewer