The Integrated Healthcare Timetabling Competition 2024: Insights, Benchmarking and Algorithmic Trends

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Abstract. The Integrated Healthcare Timetable Competition 2024 introduced the Integrated Healthcare Timetabling Problem, which combines patient admission scheduling, surgical case planning and nurse-to-room assignment into a single large-scale optimization problem. The competition attracted 32 teams from both industry and academia, who developed a diverse range of solution approaches, primarily based on mathematical programming, metaheuristics and hybrid methods. All approaches applied some form of decomposition and incorporated tailored strategies to cope with the problem's scale and combinatorial complexity. Notably, different methods performed best on different instances, and no algorithm was able to prove optimality for any instance.
This work resumes the competition setup and analyzes algorithmic trends, highlighting key methodological insights for integrated timetabling problems.

Keywords: Timetabling · Healthcare · Integrated optimization · Benchmarking

1 Introduction

Hospital resource optimization has progressed from solving isolated problems towards addressing integrated models that capture interdependencies between different planning and scheduling procedures. While prior research has addressed partial integrations, such as patient-to-room and nurse-to-patient assignment [1], fully integrated approaches remain scarce due to their computational complexity [3].

To stimulate research on these challenging problems, EURO working groups ORAHS[5] and PATAT[6] joined forces and organized the Integrated Healthcare Timetabling Competition 2024 (IHTC-2024). The competition introduced the

[5] Operational Research Applied to Health Services
[6] Practice and Theory of Automated Timetabling

Integrated Healthcare Timetabling Problem (IHTP), which combines Patient Admission Scheduling, Nurse-to-Room Assignment (NRA) and Surgical Case Planning (SCP) over a multi-week horizon with three daily shifts (early, late, night). The key decisions in the IHTP are i) selecting an admission day or postponing admission, for all patients ii) assigning patients to rooms iii) allocating nurses to rooms per shift and iv) assigning an operating theater for each patient's surgery. Various hard and soft constraints are considered, some of which relate to specific subproblems, while others arise from interactions among these subproblems. The deep integration of the three subproblems exposes the interdependencies between them. For example, patient admissions affect room and operating theatre occupancy, which in turn shape nurse and surgeon workloads and ultimately patient care.

The competition was announced at the ECCO 2024, ORAHS 2024 and PATAT 2024 conferences, and officially began on September 1st, 2024. The winners were announced in April 2025 and the award ceremony took place at the EURO 2025 conference in Leeds, UK (June 22–25, 2025). A detailed description of the problem, the competition setting and results is provided by Ceschia et al. [2], while all up-to-date information and data about the competition are available at `https://ihtc2024.github.io`.

2 Competition Design

The IHTC-2024 adopted a two-stage adjudication process to ensure fairness and robustness. After the first stage, five finalists were selected based on the mean rank of their submitted solutions for the *public* dataset. In the second stage, the organizers ran the finalists' algorithms on a *hidden* dataset under identical computational conditions (same hardware and time limits), preventing overfitting and eliminating hardware-related bias. By contrast to previous timetabling competitions, the IHTC-2024 allowed multi-core computation (up to four threads) and permitted the use of commercial solvers with academic licenses, better reflecting realistic optimization environments. Many participants embraced these new opportunities.

An important contribution of the competition is the development of a parametric instance generator capable of producing realistic and diverse scenarios, using 11 distinct parameters. A generation procedure based on the Hammersley point set ensures uniform coverage of the parameter space. The *public* dataset that was released at the start of the competition contains 30 instances with 30 to 500 patients each with a horizon of 2, 3 or 4 weeks. The *hidden* dataset consisted of an additional 30 instances of comparable dimensions, including previously unseen configurations to ensure an unbiased evaluation. Additionally, a validator tool was provided to verify feasibility and compute objective values, ensuring consistency across submissions.

Table 1. Finalists and optimization approaches.

Rank	Team	Method
1	v777v	Multi-stage MILP decomposition
2	SDU-IMADA	Metaheuristics
3	Twente	Hybrid MILP/CP/metaheuristics
4	ORTEC	Heuristic, MILP
5	UGent Mippets	ILP-based Local search, heuristic

MILP: Mixed-Integer Linear Programming; CP: Constraint Programming; ILP: Integer Linear Programming

3 Competition results

The competition attracted 32 teams, representing 16 countries across the Americas, Asia and Europe. Three main methodological categories emerged:

- **Mathematical Programming** combined with decomposition techniques;
- **Constraint Programming** integrated with heuristics;
- **Metaheuristics** primarily based on local search.

A clear trend toward hybridization was observed, with several teams combining multiple algorithmic paradigms.

Table 1 shows the final ranking of the five finalists based on their performance for the *hidden* dataset. SDU-IMADA achieved the best performance for the *public* instances, while v777v won the final evaluation for the *hidden* dataset. To quantify the disparity among finalists, a linear model was fitted to the ranks obtained for the hidden dataset. This statistical analysis confirms the superiority of the top two methods over others, with no significant difference between them, while also revealing strong instance-dependent performance variations. Importantly, no solutions were proven optimal, leaving room for additional research focusing on the computational challenge posed by the datasets.

4 Conclusions

The IHTC-2024 established a new benchmark for integrated healthcare timetabling, providing a solid foundation for future research on such complex problems. The wide variety of approaches and the lack of a universally dominant method both highlight the computational challenges posed by the problem. As future work, the benchmark could be complemented with real-world hospital instances to validate the generator's structural realism and further strengthen its value for future research.

References

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