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Application of Information Technology Tools in Addressing Specific Scheduling Challenges in Academic Timetabling*

Dorota BORKOWSKA and Anna GLADYSZ

Rzeszow University of Technology, Poland

Correspondence should be addressed to: Dorota BORKOWSKA, db@prz.edu.pl

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Abstract

The process of planning teaching activities at a university is a complex decision-making process that requires consideration of numerous organisational, staffing and infrastructure constraints. Proper scheduling not only affects the efficient use of university resources, but also the comfort of lecturers and the quality of the teaching process. This article presents a proprietary approach to the automation of academic class scheduling, based on an analysis of practical experience in preparing teaching plans. Solutions enabling the mapping of non-standard planning cases are presented. The developed methodology contributes to increasing the efficiency of the planning process, reducing the number of planning errors and improving the quality of class organisation. The implementation of effective IT tools in the planning task can significantly improve the management of the teaching process, representing an important step towards its full automation and standardisation.

Keywords: Timetabling, scheduling, optimisation, FET

Introduction

Planning teaching activities is one of the key organisational tasks in the functioning of any higher education institution. A properly prepared timetable is not just a list of hours and subjects, but a tool that has a significant impact on the quality of the education process, the comfort of teaching staff and student satisfaction. Faced with a growing number of fields of study, specialisations and forms of teaching, modern universities are faced with the need to implement increasingly advanced solutions to support the scheduling process.

The issue of schedule planning in the academic environment is a process that requires taking into account numerous constraints, such as the availability of staff, classrooms, student groups, and the number of hours for individual subjects (Ross et al.1996, Wren 1996, FET - Free Timetabling Software). Therefore, preparing an optimal plan that evenly distributes teaching loads and eliminates class conflicts is an extremely complex and time-consuming task. Many universities still use manual planning methods, which involve a lot of work, the risk of errors and low flexibility when changes need to be made.

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There are many IT tools available on the market to support the work of planners, both commercial and open source. The choice of appropriate software depends on the needs of the university, the financial outlay, the possibility of integration with existing university systems, and ease of use. An alternative to commercial solutions are open source applications, among which FET (Free Timetabling Software) stands out in particular – a tool that enables the automatic generation of timetables based on defined constraints. This software is characterised by high flexibility, an intuitive user interface and the ability to exchange data in XML format (FET - Free Timetabling Software, Das et al. 2021).

This work is motivated by the previous lack of a computer system supporting the preparation of academic timetables at the Faculty of Management of the Rzeszów University of Technology. The aim of the study is to present proposals for improvements in the process of planning teaching activities through the use of the FET programme. The proposed improvements enable the mapping of non-standard planning cases. The article presents solutions from the perspective of people who, based on their own experience with class planning and using the FET programme, share their observations and practical tips. In addition, the work is a continuation of studies devoted to the automation of the class planning process (Borkowska et al. 2025).

A comprehensive approach to scheduling, including automation of key stages of the process, eliminates problems such as overlapping classes, double room bookings and uneven teaching workloads. As a result, the proposed solution contributes to increased organisational efficiency, savings in time and resources, and improved quality of the teaching process.

Challenges and assumptions when creating a timetable

The process of creating a teaching timetable at universities is a complex, multi-stage task, subject to numerous organisational, technical and human constraints. The planner's goal is to arrange the schedule in such a way as to maximise the use of available resources – classrooms, academic staff and time – while maintaining a satisfactory quality of education and comfort for those involved in the teaching process. Effective timetable preparation requires taking into account a number of variables, whose interdependencies and constraints create a complex optimisation problem.

The complexity of scheduling

The issue of class scheduling is a classic example of a computationally complex problem belonging to the NP-hard class (Cormen 2009, Rustauletov 2020, Garey et al.1983). This means that as the number of elements increases – such as student groups, lecturers, subjects or classrooms – the number of possible combinations grows exponentially, which makes it significantly more difficult to find an optimal solution within a reasonable time. In practice, planning therefore requires the use of heuristic methods, priority rules or IT tools to support the decision-making process (Ghomi et al. 2019, Hoser et al. 2022, Li et al. 2019).

The complexity of the problem also stems from the need to reconcile many, often conflicting, criteria. The timetable should ensure, among other things, an even teaching load for lecturers, minimisation of ‘windows’ in the students' timetable, rational use of the university's infrastructure and avoidance of class collisions. Achieving a compromise between these conditions requires a flexible approach and appropriate analytical tools.

Organisational and technical constraints

One of the main challenges in the course planning process is the need to take into account organisational constraints resulting from the structure and specific nature of the university. The most common ones include:

- the availability of lecturers and their preferences regarding course dates,
- the number and capacity of classrooms,
- requirements for the equipment of specialist laboratories,
- division of students into laboratory, project, exercise and lecture groups,
- division of students into specialisations,
- the requirement to conduct classes in parallel in different fields and levels of study,
- classes conducted by academic teachers in different departments of the university.

From a technical point of view, the main problem is the integration of data from various sources – record systems, student databases, information about teaching staff and the structure of the study plan. In many cases, this data is inconsistent or incomplete, which makes it difficult to process automatically. The lack of standardisation of data formats and the need to adjust them manually significantly prolong the planning process.

Human and organisational factors

An important aspect of planning is to take into account human factors, which cannot always be fully formalised. These include, among others, individual preferences of lecturers regarding the days and hours of classes, the need to maintain the continuity of thematic blocks, or ensuring an appropriate work rhythm for students. In practice, planners often have to make compromise decisions, combining quantitative and qualitative criteria.

An additional challenge is communication between different organisational units of the university – dean's offices, organisational units and technical administration. Each of these units may have different priorities and responsibilities, which requires appropriate information flow and coordination of activities.

Planning Process Assumptions

An effective timetable creation process requires appropriate preliminary assumptions. The most important ones include (Burke et al. 1994, McCollum 2007):

1. Completeness and timeliness of input data – all information regarding the number of groups, number of hours, and availability of classrooms and lecturers must be updated before the planning process begins.

2. Standardisation of data structures – a uniform format for information enables automatic processing and minimises the risk of errors.

3. Hierarchy of constraints – it is necessary to distinguish between hard constraints (e.g. the inability of the same lecturer to teach two classes at the same time) and soft constraints (e.g. preferred class times).

4. Automation and integration – the use of IT tools that allow for the automatic generation of schedules in accordance with the accepted constraints and facilitate their subsequent modification.

5. Transparency and the possibility of correction – the planning process should allow for tracking changes, verifying results and easily updating data.

Adopting the above assumptions is the foundation of an effective and repeatable teaching schedule planning process. Their implementation not only improves the quality and consistency of the schedule, but also streamlines cooperation between those involved in the planning process. Clearly defined rules and properly prepared input data minimise the risk of errors, allow for the full use of IT tools and provide the flexibility necessary to make modifications in a dynamically changing academic environment.

Using FET software to solve unusual planning problems

The organisational, technical and human challenges inherent in the timetable creation process require the use of IT tools that enable automation and flexible adaptation to changing conditions. One of the most effective and accessible solutions of this type is the FET (Free Timetabling Software) programme – an open source application designed to automatically generate timetables taking into account a wide range of constraints. Thanks to its versatility and configurability, this programme is used not only to create standard teaching plans, but also to solve unusual planning problems that are extremely difficult to implement when planning manually (Fahmy et al. 2014, Wan Muhamad et al. 2018).

Characteristics of the FET programme

FET is software based on heuristic algorithms and random solution space search techniques. Its primary task is to automatically assign classes to specific time slots and locations in accordance with a set of defined constraints. The input

data in the programme is in the form of an XML file, which allows for easy import and export of information to external university systems, such as the University Study Service System (USOS) (Serwisy | Portal USOS), commonly used in Poland, or dedicated university databases.

FET allows you to define both hard and soft constraints. Hard constraints specify conditions that must be met without exception (e.g. a lecturer cannot teach two classes at the same time, required classroom capacity, or specific laboratory availability hours). Soft constraints, on the other hand, include preferences that the programme tries to implement as far as possible, such as avoiding classes in the late evening or spreading classes evenly throughout the week (Hoser et al. 2022). Thanks to this, FET allows you to generate timetables that are not only logically correct, but also close to users' expectations.

Flexibility in solving unusual planning problems

During the practical use of the FET programme in the process of planning teaching activities, the authors observed that one of its greatest advantages is its ability to adapt to unusual and complex planning situations that often arise in the reality of university life. Unlike many commercial systems with a strictly defined data structure and limited modification options, FET allows for flexible definition of relationships between schedule elements, which makes it extremely useful in solving problems specific to a given academic unit.

The authors' experience shows that cases requiring non-standard links between student groups, lecturers and university resources pose a particular challenge. For example, in practice, it is often necessary to:

- synchronise classes conducted simultaneously for several groups or fields of study,
- adjust the schedule to the limited availability of external specialists employed on a part-time basis,
- take into account unusual lengths of teaching units,
- take into account specific requirements for laboratory rooms or specialist workshops,
- plan classes conducted in a blended mode, including both face-to-face and remote forms.

The FET programme allows you to define such cases through a system of relationships and dependencies between classes, groups and lecturers. By skilfully using the programme's advanced functionality, it is possible to create schedules that correspond to actual teaching needs, even with a significant level of organisational complexity.

The use of FET to solve selected/unusual planning problems

In planning practice, the authors have repeatedly encountered the need to solve unusual planning problems. A number of non-standard challenges related to class scheduling have made it possible to identify cases requiring an individual approach in the class planning process.

In the organisational activities of a university, there are situations in which certain courses are taught by several lecturers, have different numbers of hours, take place in irregular cycles or require separate administrative decisions. The aim of this chapter is to present methods of dealing with special planning situations using the FET programme. Flexible mapping of planning problems is possible through the appropriate definition of activities, lecturers and time constraints. Selected examples of special planning cases are discussed below, together with the recommended method of their implementation in the FET environment, based on the authors' experience.

Case 1. Planning classes taught by a larger number of lecturers with an even distribution of teaching hours

We considered a case where the goal is to obtain a schedule in which one course with a total of 30 hours is taught to the same group of students by two lecturers in a 1:1 ratio (15 hours each). We assumed an even distribution of classes throughout the week, excluding the accumulation of both parts of the course on the same day. The FET programme does not offer a mechanism for automatically ‘proportionally dividing’ a single series of activities among multiple lecturers. In such a situation, in order to control the proportion of hours and distribution over time, separate activities assigned to different lecturers must be explicitly entered. Each activity should have a separate identifier (e.g. Mathematics – part A and Mathematics – part B) and be assigned the appropriate number of hours (Fig. 1). Each part of the class constitutes a separate series of activities, and the total number of units in the two parts corresponds to the required 30 hours. The equality of lecturers' workloads is guaranteed at the input stage. This solution maintains transparency in the data structure, facilitates

the precise enforcement of time constraints between parts of the course, and allows for the independent assignment of dates for both parts of the course, while maintaining the consistency of the subject.

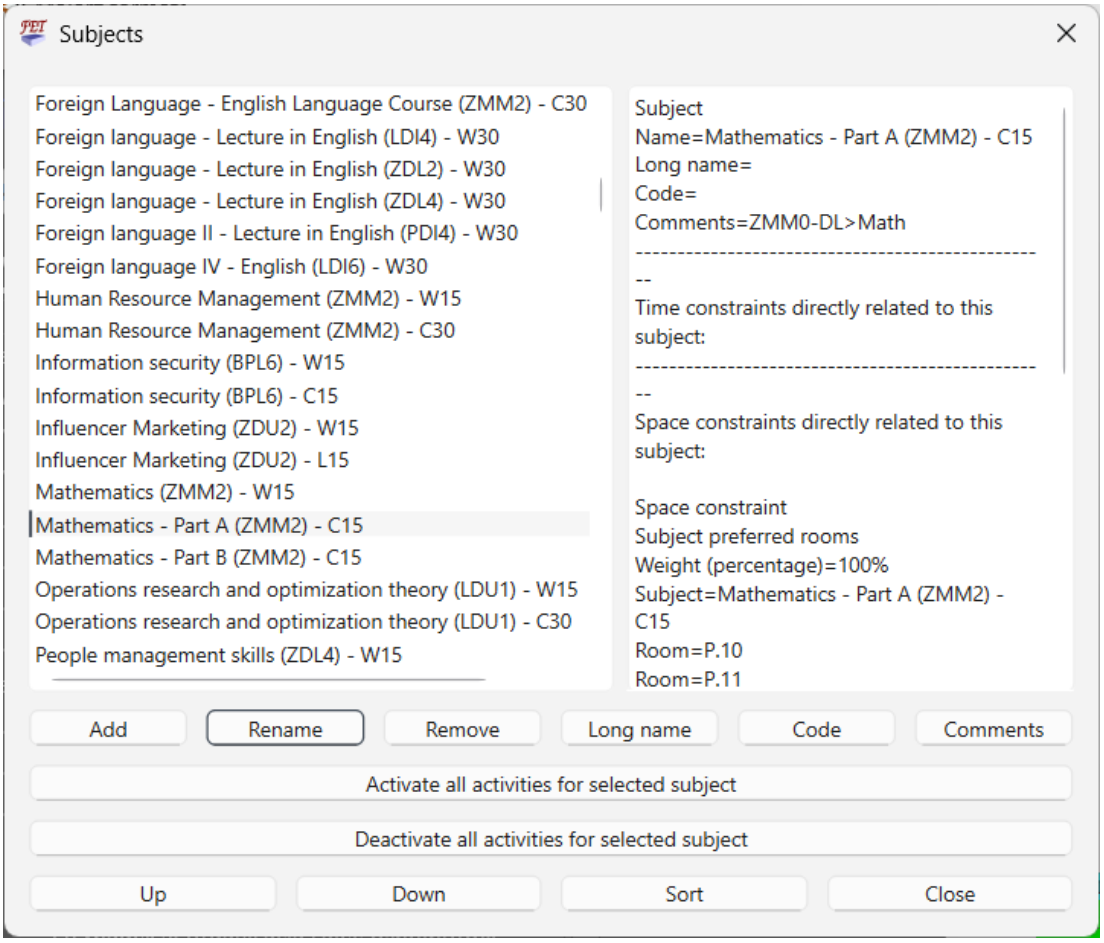

Fig. 1. Window *Data –> Subjects*

The authors recommend using the min days between activities restriction to ensure an even distribution of hours among lecturers and to avoid a situation where both parts of the course are taught on the same day. It is recommended to set the value of 1-2 for the Min days parameter and 100% for the Weight parameter (Fig. 2). This setting reduces the risk of both parts of the activity being scheduled on the same day and favours alternating the scheduling of the parts of the activity on a weekly basis.

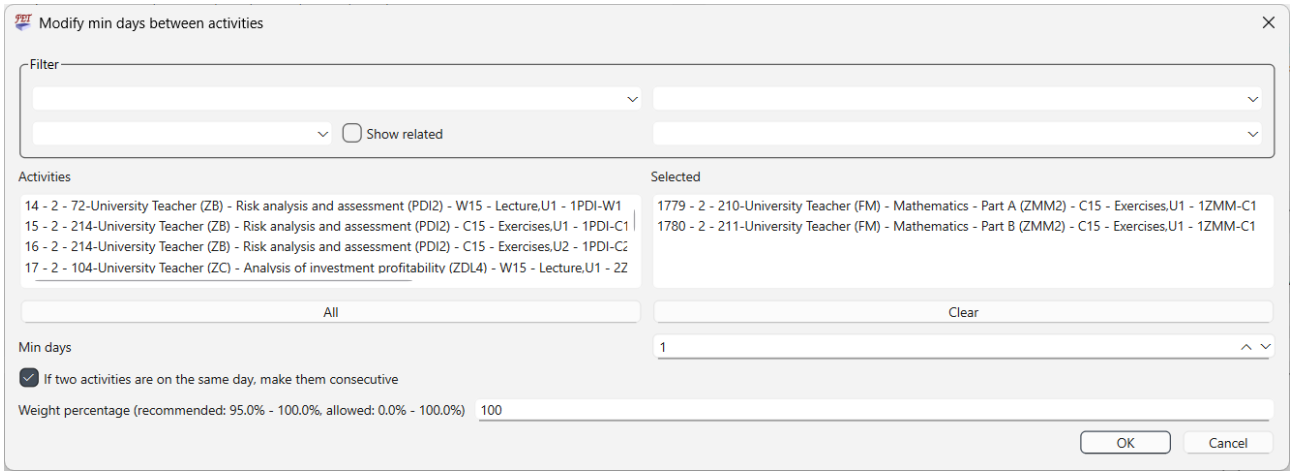

Fig. 2. Window *Time –> Activities –> Other (1) –> Min days between a set of activities*

The schedule generated in this way, with the restrictions applied and using soft preferences related to lecturer availability, allows for a balance of teaching hours between co-lecturers, while maintaining consistency in the weekly schedule.

Case 2. Planning classes taught by two lecturers with an uneven distribution of teaching hours

In academic practice, there are often situations in which the total number of hours of the analysed classes is taught by two lecturers in an asymmetrical proportion (e.g. 2:1 - 20 hours for one lecturer and 10 hours for the other), while maintaining the consistency of the subject and an even distribution of classes throughout the week. Such cases may be formally justified (e.g. coordinator – co-lecturer) or result from staffing constraints, in which one of the lecturers carries out a significantly larger part of the teaching load. The FET programme does not have a mechanism for automatically weighting a series of classes between multiple lecturers. This proportion should be encoded structurally by creating two separate activities for the same subject and the same group of students, assigning them to different lecturers with a number of sub-activities (Split into) corresponding to the actual number of teaching hours (Fig. 3). This solution ensures that the timetable is set in accordance with the target proportion of hours, while maintaining the consistency of the student group.

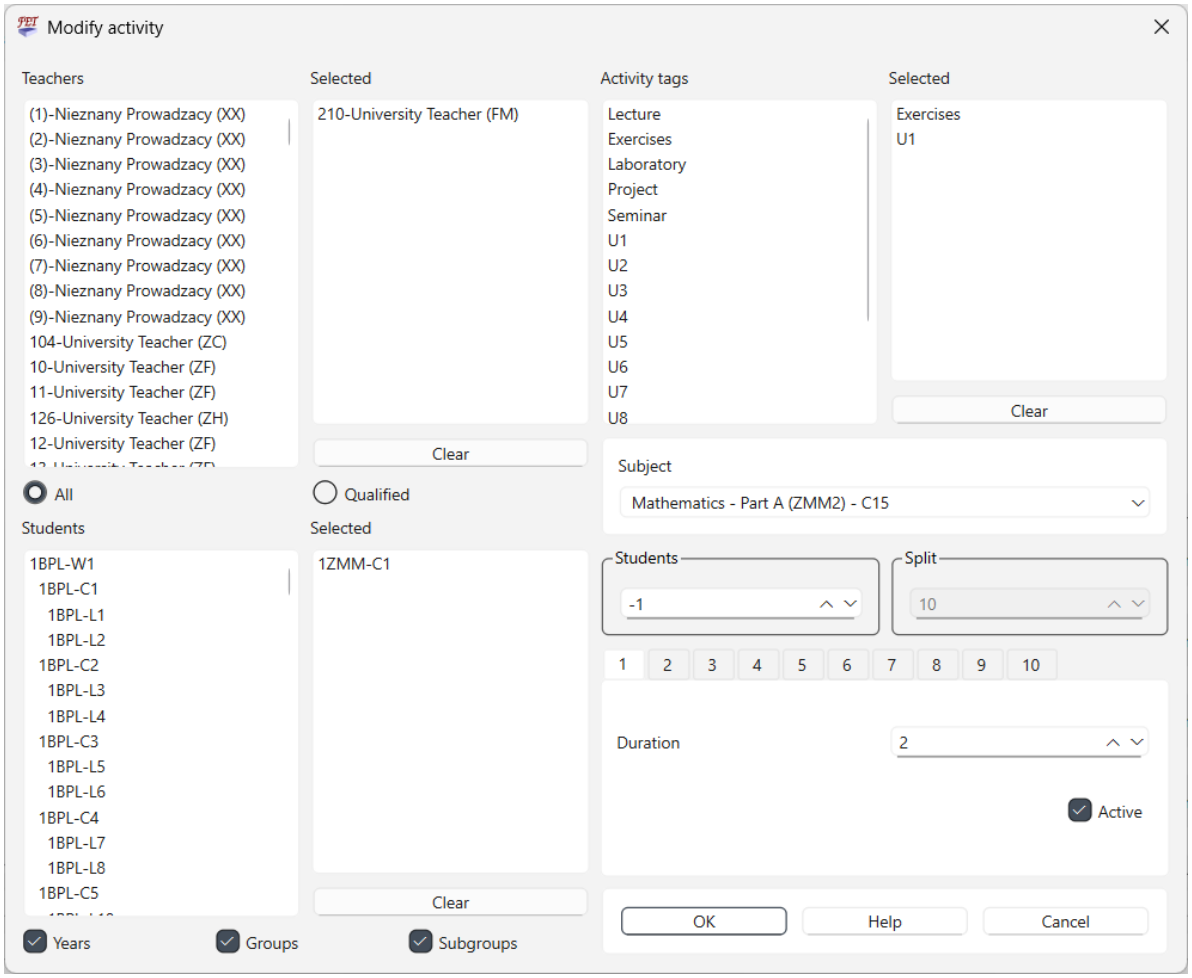

Fig. 3. Window *Data –> Activities* for the lecturer teaching 20 hours out of 30 hours of Mathematics classes

In such a situation, a steady pace of activities will be ensured by Min days between activities restrictions (between parts and within each sub-activity). If necessary, soft time preferences can be added (A set of activities has a set of preferred starting times). The authors' experience shows that this approach significantly reduces the risk of time conflicts and allows for a more realistic representation of the actual division of work between lecturers teaching a given subject.

Case 3. Organisation of classes co-taught by two lecturers teaching on separate dates

A particularly challenging case is configuring a schedule in which two lecturers teach the same subject to the same group of students, but each on separate dates, without any imposed time relationship between the parts of the classes (e.g. no requirement for alternation or avoidance of teaching on the same day). This arrangement is used when the subject areas are separate (laboratory or project classes, where different lecturers teach separate subject blocks within a single subject) and the lecturers' availability varies significantly. To reflect the independence of dates in the FET programme, two separate activities should be created for the same subject and the same group of students, with different lecturers. Do not define a time relationship between parts of separate activities for the same subject (no Min days between activities restriction set). This creates two independent series of meetings (part A and part B) assigned to the same subject and the same group of students, conducted by different lecturers on independent dates.

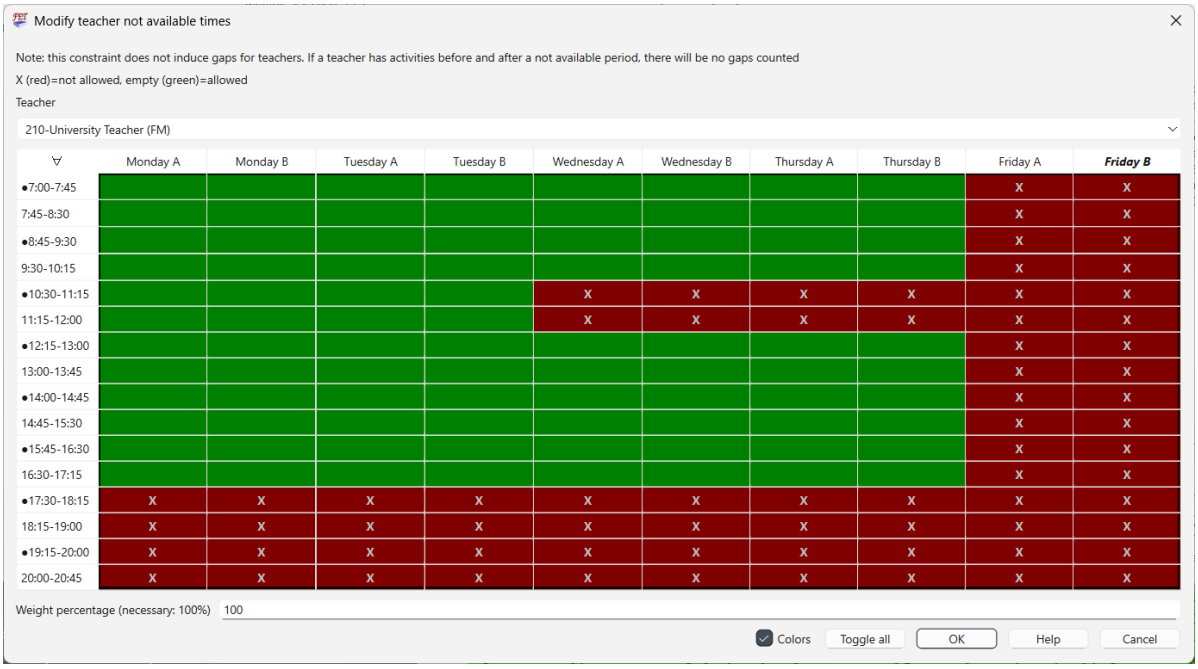

Fig. 4. Window *Time –> Teachers –> A teacher (1) –> A teacher's not available times* for the lecturer 210-University Teacher (FM)

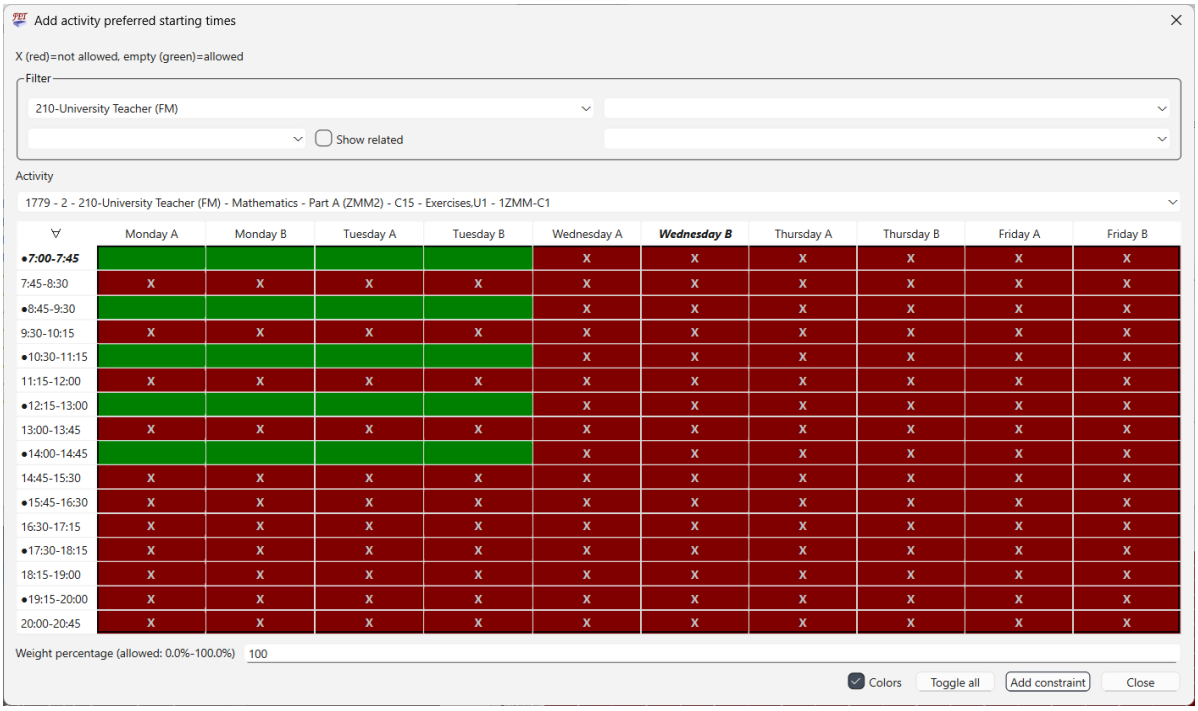

Fig. 5. Window *Add activity preferred starting times* for Mathematics – Part A and the lecturer 210-University Teacher (FM)

The FET programme generator can schedule parts of classes on the same day or on different days, depending on the availability and preferences of lecturers, without linking parts of classes for the same subject. After defining the unavailability of lecturers (Fig. 4), the authors suggest applying an additional restriction, Activity preferred starting times, for each lecturer in order to precisely match the dates to their individual preferences or availability (Fig. 5).

Case 4. Planning classes with non-standard frequency

Some classes with a small total number of hours per semester (e.g. 15 hours) may be held on a weekly basis based on an organisational decision (e.g. a decision by the dean, an agreement with the lecturer). The FET programme generates a schedule for one week of classes, which is then repeated in subsequent weeks of the semester. For this reason, the number of sub-activities in FET refers to the number of occurrences within a single week, rather than over the entire semester. To obtain a weekly meeting, classes for a given subject should be modelled as one activity per week. In practice, this boils down to adding an activity in FET for a given lecturer and group of students with a value of 2 set for the Split and Duration parameters (Fig. 6). This means setting two class units for a given subject to take place every week. The semester total number of hours is not directly coded in FET - the programme does not track the calendar of multiple weeks.

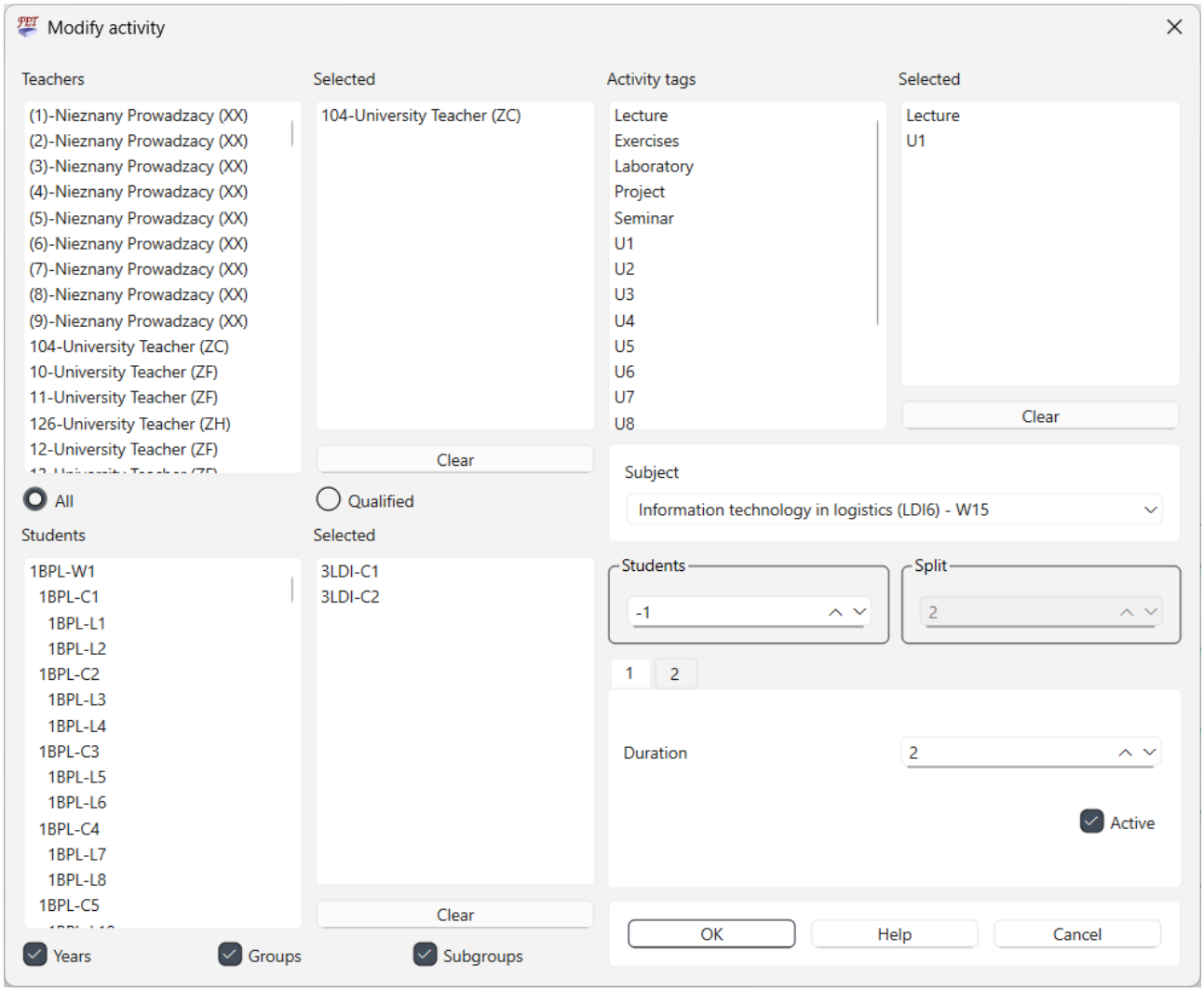

Fig. 6. Window *Modify activity* for *Information technology in logistics* and the lecturer 104-University Teacher (ZC)

In addition, the authors recommend introducing additional restrictions:

- Time -> Activities -> Other (1) -> Min days between a set of activities
- Time -> Activities -> Other (1) -> Max days between a set of activities
- Time -> Activities -> Other (2) -> A set of activites has same starting hour (any days)
- Time -> Activities -> Other (2) -> Two activites ordered
- Time -> Activities -> Preferred times -> An activity has a set of preferred starting times
- Space -> Activities -> A set of activities occupy max different rooms

This allows the programme to generate classes at regular intervals (every week), at a selected start time, in a specific classroom, which helps maintain a consistent rhythm of implementation.

The authors' experience shows that this approach improves the consistency of the schedule and makes it easier for students to organise their time, especially in the case of short, cyclical subjects. However, it is important to define time priorities appropriately so that the FET programme does not attempt to group units in a shorter period, which could lead to an excessive concentration of classes in the weekly schedule.

Case 5. Scheduling classes for a lecturer who teaches at different departments of the university

If an academic teacher teaches at more than one department, it is necessary to plan the schedule in such a way as to eliminate time conflicts, reduce the need to move between buildings, and increase its stability in the face of subsequent modifications. A key feature of the FET programme is the generation of a reference week, which is repeated in subsequent weeks of the semester, so the most effective way to separate activities between departments is to assign them separate subsets of days. For example, classes at the Faculty of Management can be held on Mondays and Tuesdays, while classes at the Faculty of Economics can be held on Wednesdays and Thursdays. Technically, this is achieved by limiting time preferences at the activity set level (A set of activities has a set of preferred starting times) and assigning selected days for implementation by a given lecturer.

At the same time, it is worth precisely managing the lecturer's availability. The Teacher not available times restriction allows you to exclude days or hours allocated to other duties (e.g. research or teaching duties), so that the search space only includes actual class times. Additional restrictions – Teachers max hours daily (limit on the maximum number of class units per day) and Teachers max gaps per day (limit on the maximum number of breaks between classes on a given day) – prevent excessive lengthening of the day and unfavourable class scheduling (Fig. 7, Fig. 8).

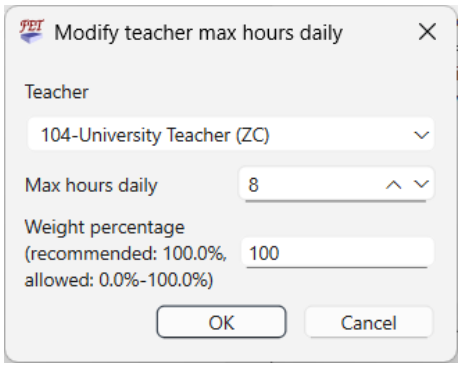

Fig. 7. Window *Time –> Teachers –> A teacher (1) –> Max hours daily for a teacher*

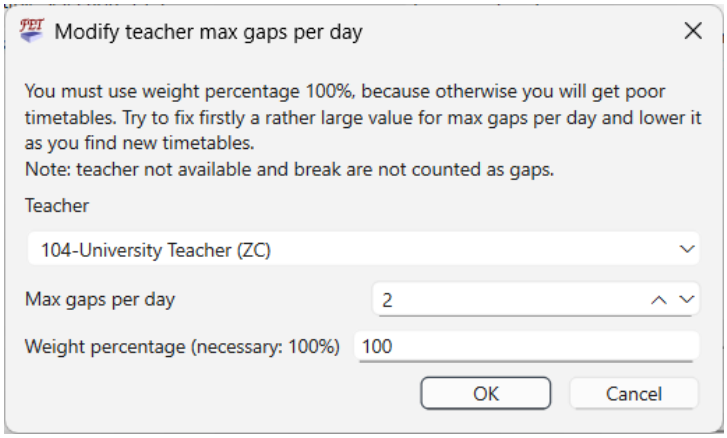

Fig. 8. Window *Time –> Teachers –> A teacher (1) –> Max gaps per day for a teacher*

The expected result is a timetable in which lecturers' classes are naturally grouped on assigned days and in the spaces of individual departments, without mutual collisions and with a limited number of transitions between buildings. This solution not only avoids overlapping activities, but also promotes the effective organisation of lecturers' working time. The authors' experience shows that precisely defining days for individual departments significantly simplifies the process of automatically generating the schedule and improves its stability when modifying input data. This solution is highly flexible. Minor modifications (e.g., changing a room or adjusting the date of selected classes) cause local (at the faculty level) rather than global rearrangements, which is crucial for iterative refinement of schedules at the university level.

Case 6. Modelling an alternating laboratory class schedule within a single exercise group

In academic practice, there are situations that require alternating laboratory classes within a single exercise group. For organisational or infrastructural reasons, such a group is divided into two subgroups using the same specialised room in different weeks, while maintaining the same class start time. Since the FET programme constructs a reference week, which is then replicated in subsequent weeks of the semester, the alternation of even and odd weeks can be most easily simulated in the data structure by extending the set of days of the week to ten (e.g. Monday A...Friday A and Monday B...Friday B). In a weekday grid defined in this way, it is recommended to create two separate activities for the same subject, assigned to two subgroups (laboratory groups) of the same student group. For these subgroups, restrictions on acceptable start slots are defined so that the first laboratory group can only start on days from set A, and the second only on days from set B. This ensures that the laboratories are located in different weeks A or B, but within the same reference week.

In order to maintain temporal consistency and clarity of the plan, the same start time should be set for both activities. The most convenient way to achieve this is to apply the restriction A set of activities has same starting time (day+hour) to the sets corresponding to the laboratory classes of a given exercise group (Fig. 9). This ensures that individual activities will take place on the same day in different weeks and start at the same time, which simplifies communication with students and lecturers.

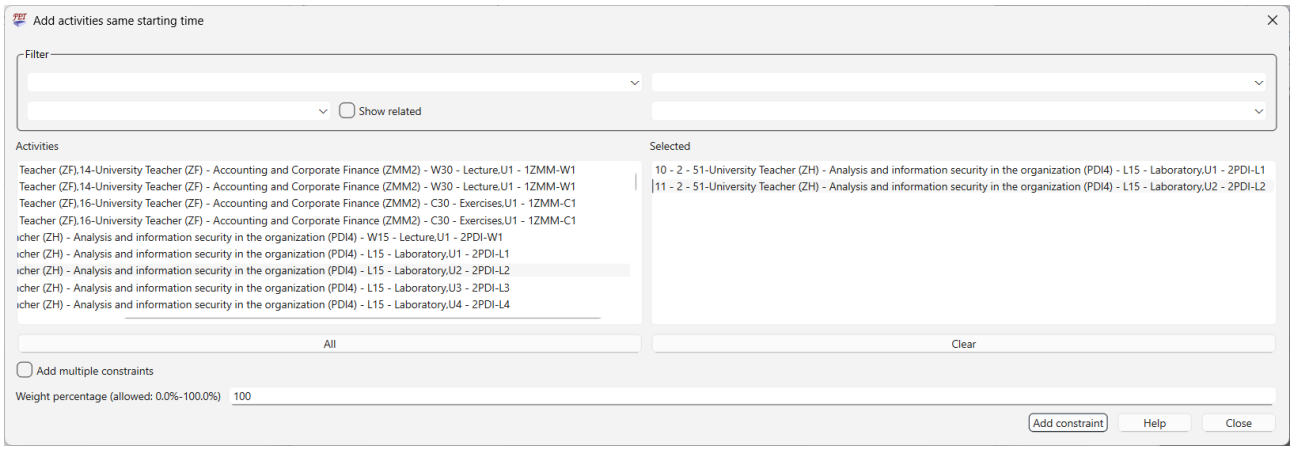

Fig. 9. Window *Time –> Activities –> Other (2) –> A set of activities has same starting time (day+hour)*

Room management is also crucial. Since both laboratory subgroups are to use the same specialist laboratory, it is advisable to assign the same room to both activities. In practice, this solution ensures full utilisation of the infrastructure and a predictable teaching rhythm (fixed day and time of classes).

Case 7. Subjects taught on a selected day due to the availability of specialist rooms and the need to prepare laboratory/teaching stations

When drawing up the timetable, there are also subjects that require access to highly specialised infrastructure (computer rooms, experimental laboratories), for which the timetable must take into account the scheduling of classes for all groups on a given day/days of the week due to the need to prepare teaching stations in advance. In the FET programme, the most effective strategy is to link the time constraints of the subject with the spatial constraints of the classrooms so that the timetable reflects both the availability of laboratory stations and the need to prepare them in advance. In practice, this is done in two steps. First, for a given specialist laboratory, the preferred days for classes are defined at the level of individual activities (An activity has a set of preferred starting times). In the second step, the subject or activities are assigned to specific rooms (A subject has a set of preferred rooms / An activity has a set of preferred rooms) (Fig. 10).

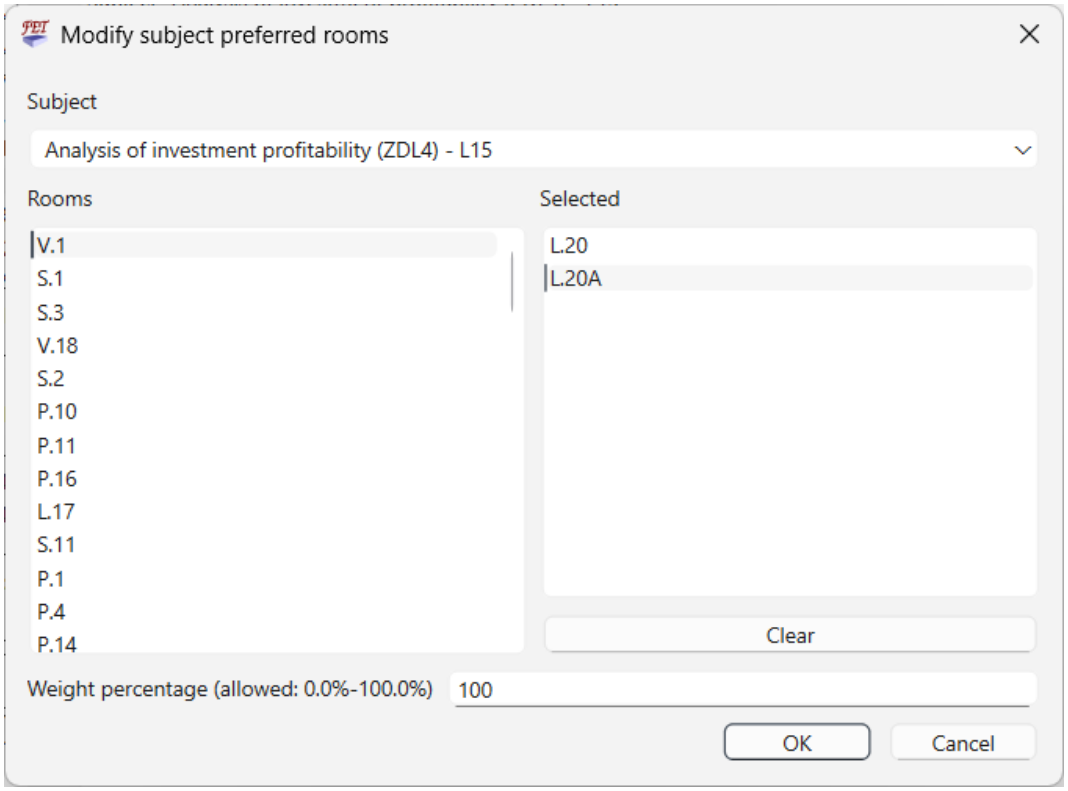

Fig. 10. Window *Space –> Subjects –> A subject has a set of preferred rooms*

As a result, the FET programme operates within a strictly defined decision-making space. Specialist classes can only take place on days designated in advance for the preparation of specialist classrooms, in clearly designated rooms and with logistical intervals for the preparation of teaching stations.

The authors' experience shows that this type of approach allows for the optimal use of specialist classrooms and prevents the inefficient booking of classes at other times.

Case 8. Organisation of classes requiring implementation within specific time frames depending on the specific nature of the teaching content

In the case of classes whose educational value depends, for example, on current access to market information (e.g. stock market quotations, financial data or institutional announcements), it is important to ensure that they can be conducted within strictly defined time slots corresponding to the operating hours of the institutions concerned. In the FET programme, this is achieved by imposing a restriction on the activity, e.g. by specifying a time slot after 3 p.m. As this is a substantive requirement, it is recommended to impose a hard restriction – assigning a weight of 100% so that the programme does not relocate classes to earlier hours. This solution accurately reflects the real conditions of conducting classes and increases their practical usefulness (working with live data). In addition, it reduces the number of iterations needed to obtain a stable solution, as the key conditions of the teaching content are already clearly encoded in the input data.

Case 9. Taking into account the limited availability of teaching staff and irregular class schedules

Sometimes a lecturer has limited and variable availability during the semester (e.g. due to other professional duties, research internships, external assignments). In such situations, it is necessary to flexibly plan classes that do not take place on a regular weekly basis. In the FET programme, this problem can be solved by defining classes that are held only in selected weeks (e.g. every other week). Separate activities are created for the same classes and assigned to subsets of days corresponding to the weeks in which the lecturer can actually conduct them (e.g. activities designated for ‘every other week’ are only allowed on days in set A). This restriction is implemented through start preferences (An activity has a set of preferred starting times) at the activity level, and teacher unavailability (Teacher not available times) is set by differentiating between sets of days in even/odd weeks (A/B). This excludes weeks when classes cannot take place from the

search space. This approach allows for a balance between the organisational constraints of the university and the individual capabilities of the staff, while increasing the stability and consistency of the timetable.

Conclusions

The aim of this paper was to develop and present solutions to improve the process of planning teaching activities in an academic environment, taking into account the use of the FET programme. The authors' experience confirms that the proper use of IT tools significantly increases the efficiency, transparency and accuracy of the class scheduling process.

The authors' own contribution includes the development of a set of practical guidelines and original methods for dealing with unusual planning cases that occur in the daily functioning of a university. Based on actual teaching data and observations of the faculty's work organisation, solutions were developed concerning, among other things, co-teaching by several lecturers, planning subjects with irregular frequency, scheduling in limited premises, and modelling classes requiring prior preparation of laboratory infrastructure.

The application of the developed methodology in the class planning process at the Faculty of Management of the Rzeszów University of Technology has yielded measurable results in the form of reduced schedule preparation time, increased data accuracy, and a reduction in errors resulting from the use of manual planning methods.

It is worth noting that the scheduling process at the Rzeszow University of Technology is carried out independently by individual departments, which requires a high level of flexibility and adaptation of tools to local organisational needs. The developed solutions have enabled the creation of a unified yet scalable approach that can be successfully adapted by other university units.

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