# The Higher Educational Information System: Management of the Timetable Scheduling

Liudmyla Koliechkina[1], Olena Dvirna[2], Yuri Ivanov[2], Kseniia Verhal[2]

[1] *Algorithms and Databases Department, University of Lodz, Narutowicza 68, Lodz, 90136, Poland*
[2] *National University "Yuri Kondratyuk Poltava Polytechnic", 24, Pershotravneva Avenue, Poltava, 36011, Ukraine*

**Abstract**

Automation of educational activities is an important strategic direction of a higher educational institution development in today's conditions. One of the components of the implementation of the information system of a higher educational institution is the creation of a schedule. The Timetable Scheduling Module should provide work with big data and have the appropriate software and technical infrastructure, analytical tools, reporting units, and error detection units. The paper examines certain aspects of the schedule creation module. A description of the software and hardware infrastructure for business process of forming the university schedule is given.

**Keywords**

Information system, higher educational institution, schedule, curriculum, students, system architecture

## 1. Introduction

In modern conditions, society have been facing with the need of an ongoing digitalization of the activity in all sectors activities of the economy, including the field of higher education as a central venue for the creation of new knowledge economies for the 21st century [1]. Under the influence of the rapid expansion of COVID-19 epidemic, the russian federation's military war of aggression against Ukraine higher education institutions of Ukraine are undergoing digital transformation. The information technologies and systems, learning technologies and digital platforms are actively implemented to meet the needs of students and faculty, since these needs are critical for teaching and learning. Trying to absorb the shock, students, academic staff, and administration embarked on a fast experimentation and learning process on how to teach, learn and administer digital education [2]. The study plan is the main foundation of the educational process in any academic institution that determines the content all training activities that each student must undertake during its university career. The study plan specifies a list of educational components and their logical sequence according to the state educational standard, implements the basic principles of subject selection, regulates the total academic load and the volume of academic disciplines, the student's workload by periods of study, forms of final control. Given the complex structure of the study plan, the generation of the schedule of the university's educational process is important component of the educational process, its quality and efficiency. Considering the lack of automated information systems in universities the process of building student's schedule is considered one of the chronic problems facing the educational process in many educational institutions [3]. The university course schedule is the main, final planning document that regulates the educational work of students and educational staff. The problem of drawing up a

ProfIT AI 2023: 2nd International Workshop of IT-professionals on Artificial Intelligence (ProfIT AI 2023), November 20–22, 2023, Waterloo, Canada

lkoliechkina@gmail.com (L. Koliechkina), lenadvirna@gmail.com (O. Dvirna), tristar1707@gmail.com (Y. Ivanov); vergal.ks@gmail.com (K. Verhal);

0000-0002-4079-1201 (L. Koliechkina); 0000-0002-0750-6958 (O. Dvirna); 0009-0008-2518-9264 (Y. Ivanov); 0000-0001-6611-0489 (K. Verhal)

schedule at the university is to distribute a set of courses according to the curricula within the given number of classrooms and time periods (pairs).

## 2. Related Work

The informatization of universities has become one of the main issues of higher education management in the digital age.

Almaraz et al. [4] define the digitalization of HEIs. This research is focused on digital transformation challenges in higher education institutions. Jackson [5] presents the research into managerial strategy, pitfalls and pivots of digital transformation. The issues related to the theoretical model of digital transformation in the HEI is presented in research [6]. The authors of the paper [7] consider five general assumptions that hinder the digital transformation of HEIs. In [8], the authors consider the problems of the digital transformation of higher education after COVID-19. Paper [9] considers a key aspect of the digital transformation of higher education - the creation of a digital learning space.

The Bologna process, proposed in 1999, tends to harmonise HE systems throughout Europe in order to ensure compatible degree structures, equal academic qualifications and enhancing the attractiveness of foreign students to study across Europe [10]. Structural convergence of HE systems in Europe, generalized view of characteristics in HEIs, more complex and standardized HEI systems, became an important task of universities [11]. Globalisation of HE stimulates the use of more advanced information and communication technology [12]. Universities and colleges of many countries of the world are constantly searching for tools used to automate educational processes. Such tools are mainly focused on the selection of educational process management systems, electronic document flow management systems, educational activity support systems, virtual learning environment for providing distance education.

Information systems in higher education institutions are designed to manage and organize the vast amount of data that is generated in these institutions. These systems provide a platform for storing, processing, and retrieving data related to student records, financial aid, academic programs, faculty, staff, research, and administrative operations.

Usually, educational institutions use corporate information and analytical systems (IAS) [13], which are usually commercial products and require considerable costs for the purchase of licensed software (software products of automation of the process of creation and management and examinations of MedMe, BeAxi from KindGeek, (England) [14], software for the development of the system of accounting the student body Lotus Notes/Domino from IBM, (USA) [15]). The main disadvantages of using such information systems for Ukrainian universities are the English-language interface, high cost and the failure to take into account the specifics of domestic institutions of higher education.

Some of the key information systems used in higher education institutions include:

- Student Information System (SIS): SIS is a comprehensive database that stores and manages student-related data, such as registration, enrollment, grades, and transcripts. It also includes features for course scheduling, degree audit, and student communication.
- Learning Management System (LMS): LMS is an online platform used to deliver and manage course content, assessments, and communication between faculty and students. It also includes features for tracking student progress and performance.
- Financial Information System (FIS): FIS is used to manage financial data related to tuition fees, financial aid, scholarships, and grants. It also includes features for budgeting, accounting, and reporting.
- Human Resources Information System (HRIS): HRIS is used to manage employee data related to hiring, payroll, benefits, and performance evaluation. It also includes features for tracking employee attendance and leave.
- Research Information System (RIS): RIS is used to manage research data related to grants, funding, publications, and collaborations. It also includes features for tracking research progress and outputs.

These systems help higher education institutions to streamline their operations, improve efficiency, and enhance the student experience. They also provide valuable insights into institutional performance and help in decision-making processes.

However, quite often the automation of higher educational institutions builds on disparate tools that are not combined into a single system for solving functional problems. Moreover, separate software tools have their own information bases for each functional problem, do not cover all objects and processes of the HEI activity, and do not take into consideration the peculiarities of a particular university (a comprehensive educational scheduling system UniTime [16]).

The use higher educational information system should ensure [17]:

1. In educational activities:
   - creation of a modern distributed educational and methodological environment university;
   - utilization of Internet technologies in the educational process.
   - implementation of e-learning.
   - facilitation of the export and import of educational services in the international educational space.
2. In scientific activities:
   - presentation of the scientific potential of the university in the global information space;
   - access of scientific staff to the information resources of world scientific centers;
   - implementation of joint research and projects as part of international consortia.
3. In the university management:
   - management of the processes of collection, storage and processing of information about the university facilities, data search and analysis;
   - provision of automated control of the execution of decisions;
   - improvement of educational institution management planning;
   - improvement the efficiency of the use of financial and material and technical resources.

But in their implementation, information systems have two groups of problem, namely technical and non-technical [18]. The technical aspects related to systems itself, namely the quality of technical information system. In contrast, the non-technical aspects are associated with the perceptions of users op an information system that cause them to accept or refuse to use an information system.

At present, universities of Ukraine have implemented and are using a number of automated educational process management systems, namely [17]:

- Academic Information System (AIS) «STEP 5 PROF» [http://gavah.com.ua];
- AIS «Direktiva» [http://www.kitsoft.com.ua];
- AIS «University» [http://www.unitex.com.ua];
- A package of computer systems of "Polytek-soft" PE [http:// www.politek-soft.kiev.ua.];
- Program complex “ALMA-MATER” [http://www.direct-it.com.ua];
- AIS "Higher Educational Institution" [http://ndipit.com.ua];
- IS "University" [http://www.kspu.edu];
- The electronic management system of the university «Socrat» [http://vsau.vin.ua/]
- Program complex "Automated educational institution management system" [https://mkr.org.ua/].

The information systems listed above automate the main structural divisions of the higher educational institution - the dean's office, the academic department, the admissions committee, the personnel department, the accounting and financial department, etc.

The main processes that can be automated in the presented automated systems include:

- management of the educational process;
- management of the introductory campaign;
- management of information resources;
- management of financial and economic activities;

- management of scientific work.

The analysis of the information systems of the automation of the activities of the higher educational institution carried out in the article [17] allow to determine the following characteristics of higher educational information system:

- open architecture;
- modular designs;
- cross-platform architecture;
- minimization of client software requirements;
- differentiation of user access rights;
- simultaneous access by multiple users;
- network security controls.

## 3. Systems design

iZETA is an automated system of planning, organization, management and control of the educational process in higher educational institutions. The system is designed to create, support, process and save information about the components of the educational process; automation of document flow in planning, organization, management and control of the educational process; information and analytical support of all units of the educational institution. The system covers all stages from the formation of educational plans to the preparation of the timetable scheduling and the formation of accounting data for the completed teaching load by the teaching staff of the university. The purpose of creating the software package is to obtain reliable and complete information about the educational process in a timely manner, as well as to reduce the labor intensity of inputting and analyzing accounting information, increasing efficiency, consistency and reliability of data. A software package implemented on the basis of client/server technology. The database server uses the MySQL DBMS version 5.0 and higher, which ensures high reliability of data storage and integrity. The client interface language of the system is Ukrainian. Most of the printed forms automatically generated by the system are internal format reports that can be exported in MS Excel or MS Word format, saved as individual files with the option for additional individual editing and printing. The operating system required for installing the client system is Windows 2000/2003/XP/Vista/7/8/8.1/10. Work logs make it possible to monitor each user's access to certain system data. With the help of the "iZETA-Updater" tool, system modules are automatically updated.

Primary data is formed through a system of directories that make it possible to accumulate the following information in the database:

- list of educational institutions (branches of the main educational institution);
- list of university classrooms;
- list of education programs;
- list of departments of the university;
- list of academic disciplines;
- information about academic staff and employees of the university;
- list of full-time and part-time positions;
- hourly wage tariff grid;
- categories of administrative documents;
- templates of printed forms etc.

The access of authorized users to work with system modules is regulated through the administration module. With the help of a multi-level system of access regulation in one information field, users of different departments and departments of the educational institution can interact.

The system has a modular structure. Each submodule is called by the main module, and each submodule completes a relatively independent function. Each submodule can be developed,

tested, and modified independently and finally forms the whole system, so the system has good scalability. The system is divided into twelve modules:

- Management of the study plan;
- Editor of the study plan;
- Consolidated educational process timetable;
- Management of the Consolidated streams;
- Teaching load calculations;
- Teaching load distribution;
- Timetable scheduling;
- Management of the teaching load;
- Business trip manager;
- Management of publishing of printed products;
- Administrative documents management;
- Printing documents on higher education;

The system structure is shown in Figure 1.

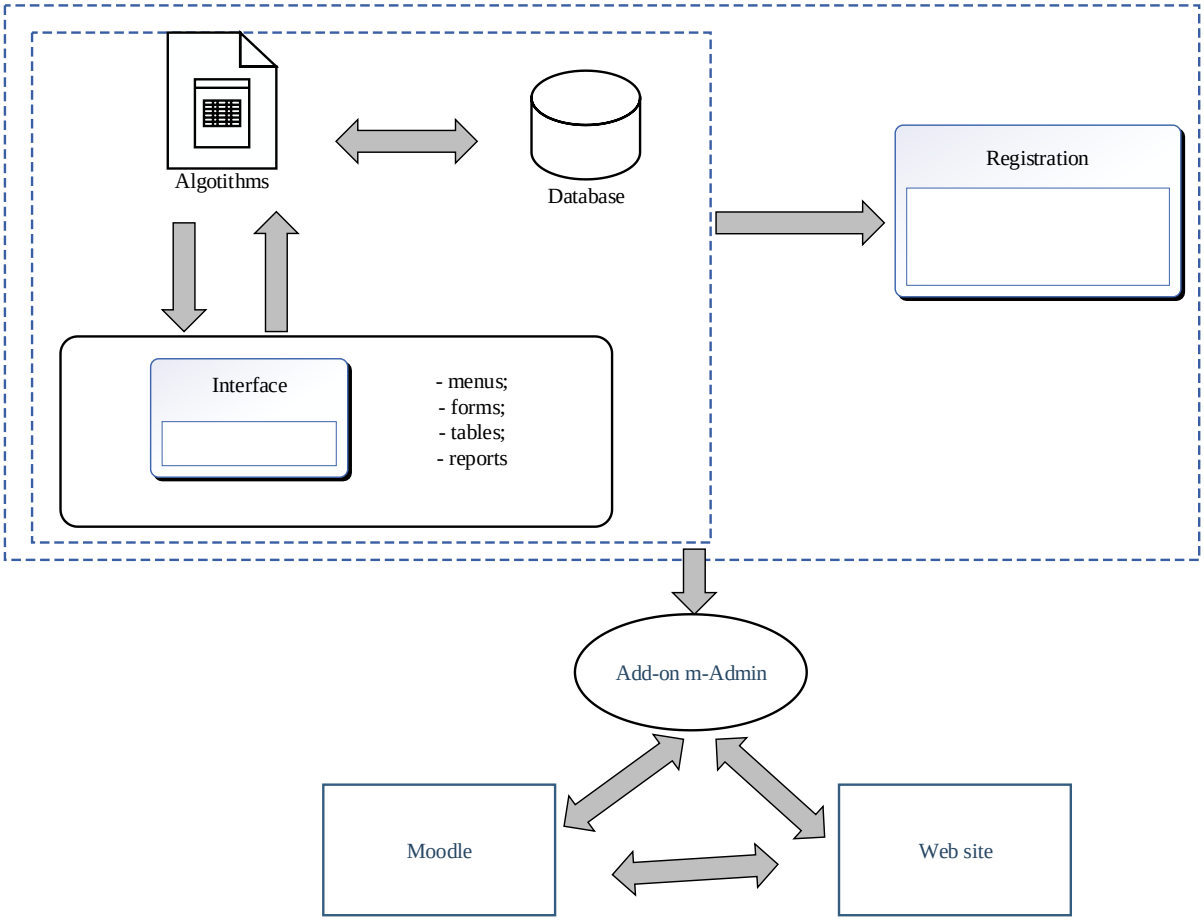


**Figure 1**: Top level components of iZETA

The server part of the iZETA is the intermediary between the database and users' applications. The main tasks of the server part are transparent access of clients to the database, ensuring the simultaneous operation of all users and synchronization and data exchange between users. The architecture of the software is designed in such a way that all users work in a single information space. So, the changes made by one user are instantly visible to all other users.

The interface handles the different menus, forms, data management, schedule management (Web site with schedule for students and academic staff), report management, and user management.

Schedule formation is computationally complex problem of distributing sets of resources to support the curricular needs: accessible workforce, courses, appropriated classrooms, labs, and working days of academic staff and student. “The allocation of given resources to specific objects being placed in space time, in such way as to satisfy as nearly as possible a set of desirable objectives, subjected to constraints.” The presence of knowledge for creating timetabling software has led to new insights, like improved methodologies and more comprehensive models [19]. Timetable must meet a number of requirements and should satisfy the desires of all entities involved simultaneously as well as possible. The timing of events must be such that nobody has more than one event at the same time [20]. The architecture of the program module Timetable scheduling Module consists of such main components, represented in Figure 2.

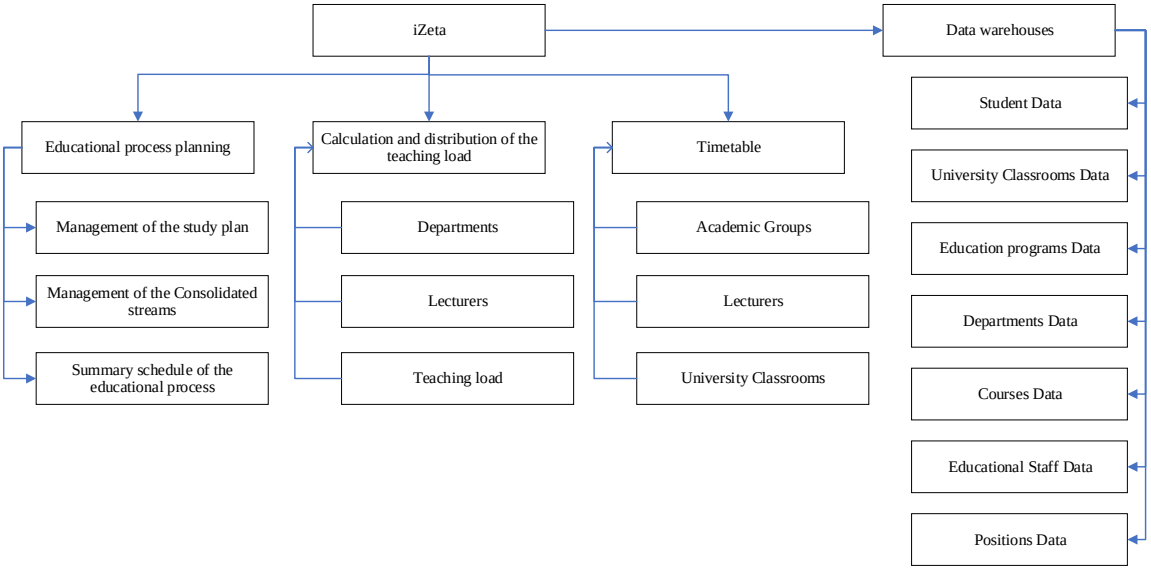


**Figure 2:** The main component of the Timetable scheduling Module

This structure allows to meet the specific requirement of the system, including scalability and maintainability. This Timetable scheduling Module is able to handle large amount of data and flexible to adapt to changes in the scheduling requirements. This module performs the main functions, such as:

- formation of a list of university classrooms with the selection of their types - lecture classrooms, laboratories and seminar classrooms, multimedia and computer classrooms (Figure 3);

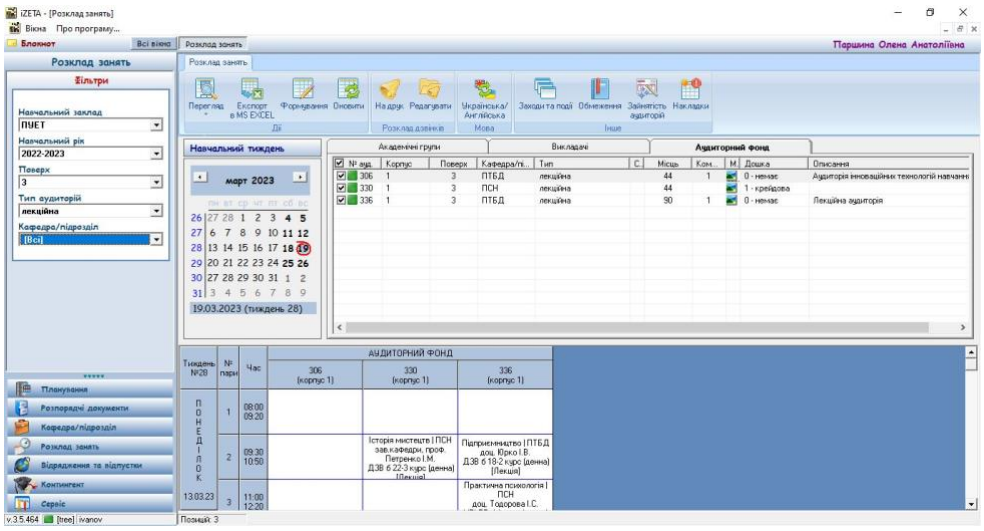


**Figure 3:** The interface for choosing the university classroom

- formation of the schedule for the current academic year for the corresponding educational institution in a semi-automatic mode;
- analysis of the formed schedule for the presence of critical inconsistencies for each academic staff member;
- analysis of the workload of the classrooms for the specified period;
- blocking in the schedule for the academic staff member due to his business trip or vacation;
- generating printed forms of relevant documents, exporting them to MS Excel file format.

The architecture of a Timetable scheduling Module includes several layers or components, such as:

- User interface layer: This layer provides the user interface for administrators or scheduling managers to input data, configure scheduling rules and constraints, view schedules, and generate reports (Figure 4).

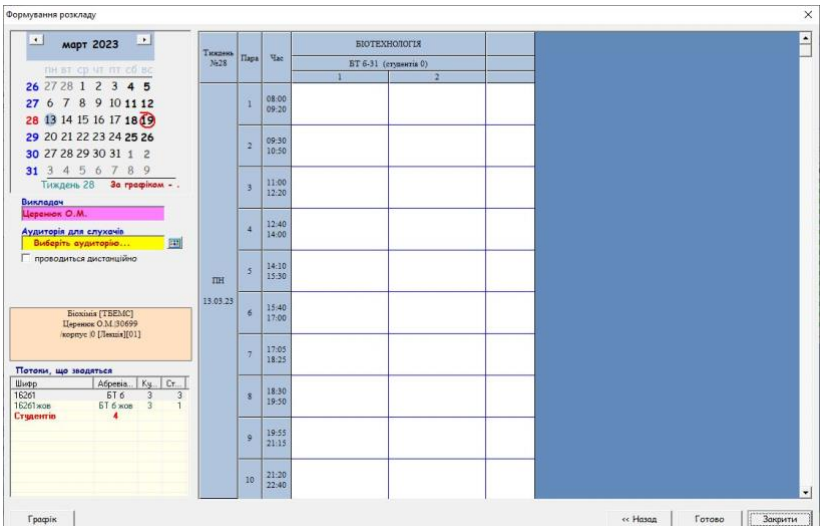


**Figure 4:** The interface for scheduling managers to input data

- Data layer: This layer stores all the data needed for scheduling, such as course offerings, academic staff availability, room availability, and scheduling rules and constraints. In the presented system, the module interacts with the database, calling the following data references: Student Data, University Classrooms Data, Education programs Data, Departments Data, Educational Staff Data, Courses Data, Positions Data.
- Scheduling engine layer: This layer includes the algorithms and rules that optimize the schedule based on the input data and constraints.
- Reporting layer: This layer provides report on various aspects of the scheduling process. These reports help managers to make informed decision about resource allocation and course offering.
- Integration layer. This layer allows for integration with other modules of iZETA (Figure 2). It enables the module to exchange data, ensuring consistency and accuracy across the entire system.
- User presentation layer. This layer provides the user web interface for the module, allowing users to interact with the system and schedule. The layer distributes information through a browser. So, the user can send requests to the server, and display the results returned by the server.
- Error handling layer. This layer is responsible for identifying, reporting, and handling errors that occur during the operation of the module. It provides mechanisms for detecting, reporting, and handling errors, ensuring that the system operates smoothly

and efficiently. When an error is detected, the error handling layer generates an error message that describes the nature of the error. The error message is displayed on the user interface (Figure 5).

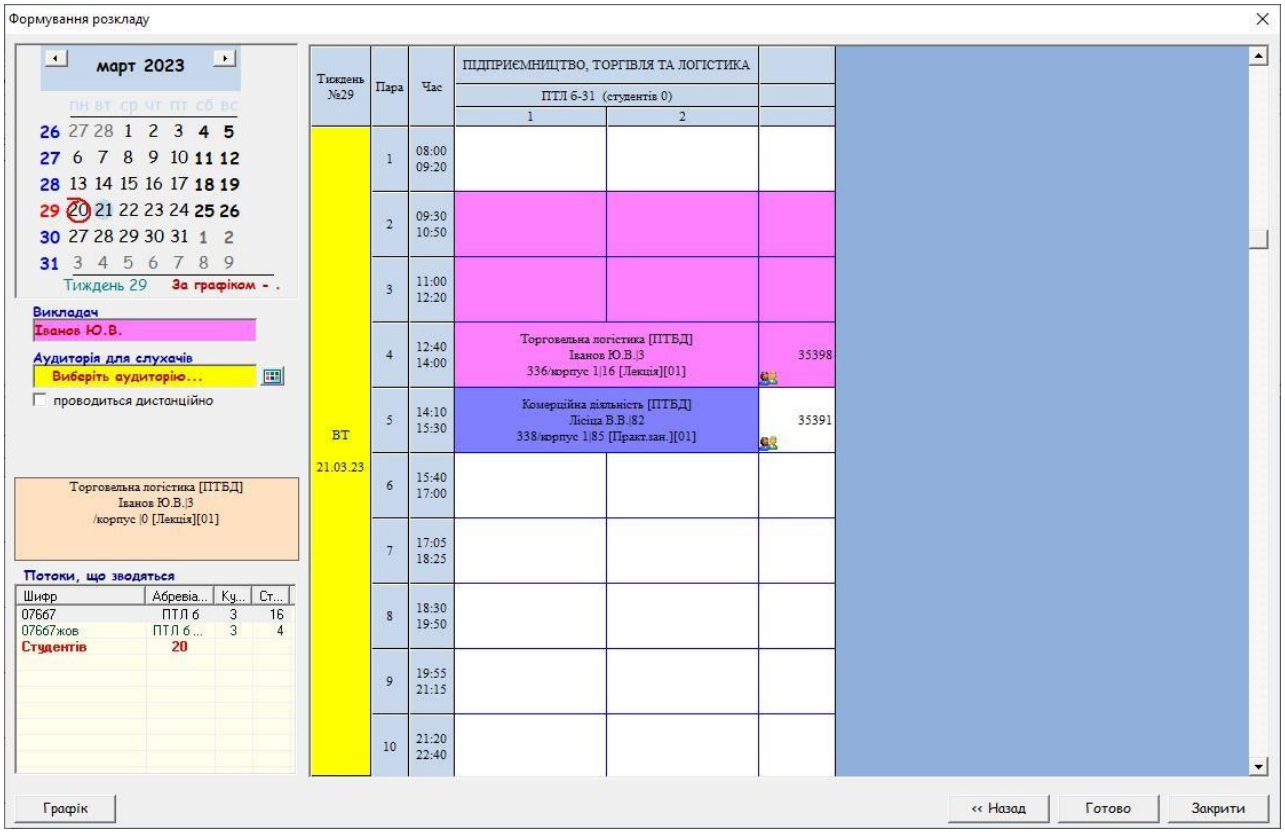


**Figure 5:** The interface for error handling

During the schedule formation, the system monitors three crucial components of the module: the teacher's schedule, classroom availability, and group schedules. If the system identifies an error at least in any of these components, courses cannot be scheduled for a specific time or in a particular classroom. Each component's availability is represented by a specific color. For instance, in the figure, the purple color indicates group availability, while the pink color represents teacher schedules. To prevent conflicts in the schedule grid, such as when a teacher is simultaneously assigned to multiple groups, changes are automatically reflected for all users whenever adjustments are made to the schedule. Following this approach, dispatchers responsible for creating the schedule can track real-time changes and identify any overlay errors.

In Timetable Scheduling Module there are some constraints that are detected using the Error handling component [21]:

- Lectures should not have timeslot clashes.
- None of the room could be used for two different lectures at same time slot.
- None of the lecturer should have two classes at same time slot
- Every classroom must be scheduled exactly once at same time slot.
- The working hours should be according to teaching load.

The schedule adjustment capability enables Schedule Managers to manually fix schedules in order to apply constraints that are not implemented by the auto-scheduler function of the system.

The architecture of the software module is designed in such a way that all schedule makers work in a single information space. Changes made by one schedule maker are instantly visible to all other schedule makers. According to this approach, the dispatchers that make up the schedule can track changes in real time and see any kinds of overlays.

The key actors for the proposed program module “Timetable scheduling” include Administrators, Education department, Schedule Manager, Head of department, Lecturers, and Students (Figure 6).

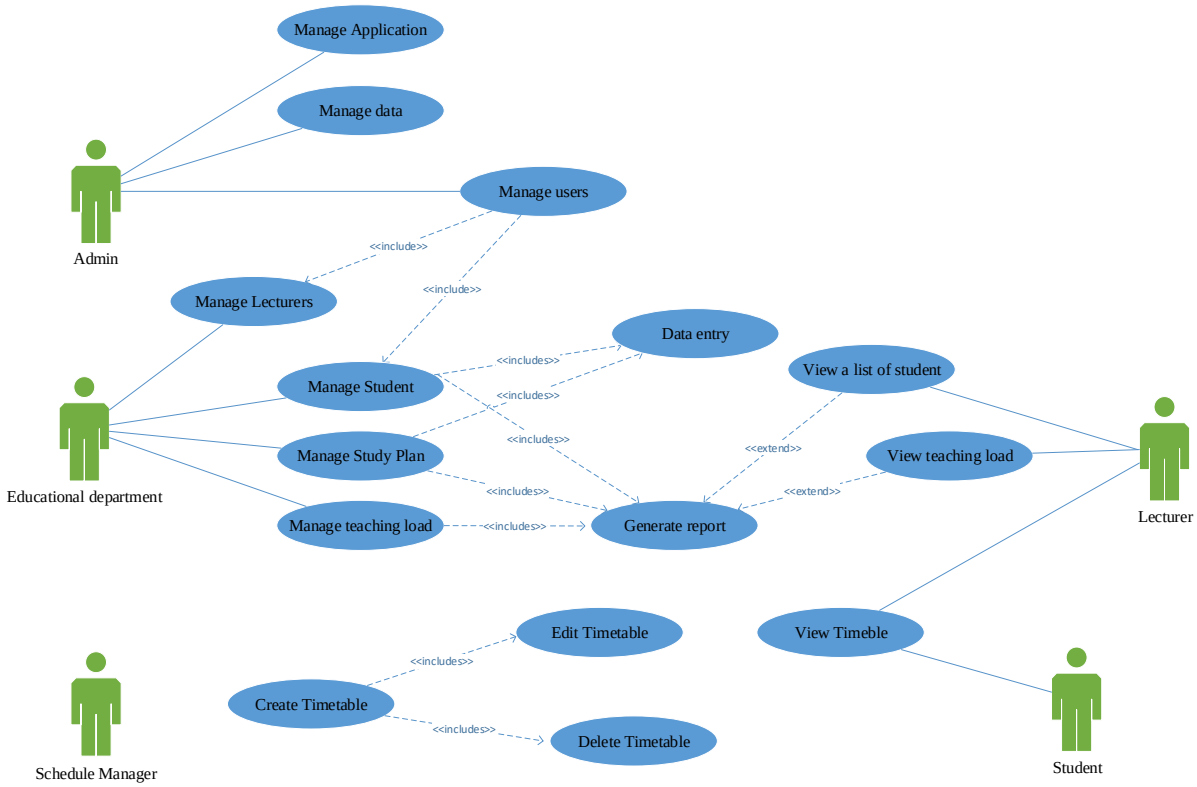


**Figure 6:** Use case diagram

The Administrator manages the application, access rights and data warehouse. The Education Department is responsible for education planning: study plans, teaching load, student’s data and academic staff data. The responsible employee of this department is engaged in updating data in warehouse, creating, and editing of the study plans, monitoring the distribution of teaching load. Report management enables the users to view or print schedule reports. Students and Lecturers management allows the Education Department to edit other possible users of the system.

The schedule manager is responsible for scheduling and managing the overall Timetable Module. Students and Lecturers, and other guest users in general may view schedules through the relevant website.

## Conclusions

An automated system (iZETA) was provided for the process of planning, organization, management and control of the educational process in higher educational institutions. The paper explains the work of the Timetable Scheduling Module of this system. The paper has contributed directly to improving the work on scheduling by automating the work of the Schedule managers. The program can be used for the general automation of the activities of a higher educational institution, including the work of the educational department.

The system was implemented in two universities in Ukraine, and it received several favorable reviews during its operation, highlighting improvements in various departments. The main positive aspects of the system include:

- Quick generation of reports and documents related to student documentation, such as orders and study plans.
- A convenient and intuitive program interface.

- A small program volume with low system requirements for installation.

- The real-time access to course schedules and grades is incredibly helpful. It has made tracking an academic progress much easier.

Program users have also put forward a number of proposals related to improving the system, which will be taken into account in further modifications. These include:

- The development of a mobile version of the schedule, adapted for Android and iOS.

- Integration with external tools like Google Calendar or task management apps, which would enhance the system's usability for organizing assignments and deadlines.

## References


[1] C. Sam, P. Van Der Sijde. Understanding the concept of the entrepreneurial university from the perspective of higher education models. Higher Education, 68 (2014): 891-908.

[2] J. Crawford, K. Butler-Henderson, J. Rudolph, B. Malkawi, M. Glowatz, R. Burton, P. Magni, S. Lam. COVID-19: 20 countries' higher education intra-period digital pedagogy responses Journal of Applied Learning & Teaching, 3 (2020): 1-20.

[3] Mozamel Saeed, Ahmed Fahim. Designing a smart system for building student's schedule-An application at Neelain University. International Journal of Advanced and Applied Sciences (2021): 82-94.

[4] Almaraz, F., Machado, A. M., and Esteban, C. L. Analysis of the digital transformation of higher education institutions: a theoretical framework. EDMETIC 6, (2017): 181–202.

[5] N. C. Jackson. Managing for competency with innovation change in higher education: Examining the pitfalls and pivots of digital transformation. Business Horizons, 62 (2019): 761-772.

[6] H. L. Mora, P. P. Sanchez. Digital Transformation in Higher Education Institutions with Business Process Management: Robotic Process Automation mediation model in: Proceedings of the 15th Iberian Conference on Information Systems and Technologies (CISTI), 2020. doi: https://doi.org/10.23919/cisti49556.2020.9140851.

[7] M. Kopp, O. Gröblinger and S. Adams. Five Common Assumptions That Prevent Digital Transformation at Higher Education Institutions, in: Proceedings of the 13th International Technology, Education and Development Conference, Valencia, 11-13 March 2019, pp. 1448-1457, doi: https://doi.org/10.21125/inted.2019.

[8] Adam Marks, Maytha AL-Ali, Reem Atassi, Abedallah Zaid Abualkishik and Yacine Rezgui. Digital transformation in higher education: a framework for maturity assessment, All Works. 4073, 2020. URL: https://zuscholars.zu.ac.ae/works/4073.

[9] M. Dæhlen. From dual digitalization todigital learning space: Exploring the digital transformation of higher education. Computers & Education, vol. 182, 104463, 2022. doi: https://doi.org/10.1016/j.compedu.2022.104463.

[10] P. G. Altbach, and J. Knight. The Internationalization of Higher Education: Motivations and Realities. Journal of Studies in International Education, 11, (2007): 290-305.

[11] R. A. Oude Vrielink, E. A. Jansen, E.W. Hans, et al. Practices in timetabling in higher education institutions: a systematic review. Ann Oper Res 275, 145–160 (2019). https://doi.org/10.1007/s10479-017-2688-8

[12] G. Philip, L. Altbach, L. Reisberg, E. Rumbley. Trends in global higher education: Tracking an academic revolution. The Netherlands: Brill, 2010. doi: https://doi.org/10.1163/9789004406155

[13] M. M. Kosiyuk, K. E. Bilovskyi, and B. M. Lysak. Automated Information Management System of Higher Education Institution «Electronic University», ITLT, vol. 93, no. 1, (2023): 96–116.

[14] M. Bogdan How to Develop a University Management Software (2019). URL: https://kindgeek.com/blog/post/how-to-develop-a-university-management-software

[15] M. Elhoseny, N. Metawa, A. E. Hassanien, An automated information system to ensure quality in higher education institutions, in: Proceedings of the 2th International Computer

Engineering Conference (ICENCO), 2016. doi: https://doi.org/10.1109/icenco.2016.7856468
[16] UniTime | University Timetabling. URL: www.unitime.org.
[17] V. G. Gritsenko. Nowadays analysis of using information and communication technologies in the universities management. Collection of scientific papers Kamianets-podilskyi national Ivan Ohiienko university. Pedagogical Series. no. 20 (2014): 256-259.
[18] M. A. Murtadho, F. Wahid. Permasalahan Implementasi Sistem Informasi Di Perguruan Tinggi Swasta. Jurnal Ilmiah Teknologi Sistem Informasi, 2(1) (2016): 17-21.
[19] B. McCollum, N. Ireland. University timetabling: Bridging the gap between research and practice, in: Proceedings of the international conference on the practice and theory of automated timetabling (PATAT), 2006.
[20] R. J. Willemen. School timetable construction: algorithms and complexity. [Phd Thesis 1 (Research TU/e / Graduation TU/e), Mathematics and Computer Science]. Technische Universiteit Eindhoven (2002). https://doi.org/10.6100/IR553569
[21] Perumal Sundresan, Tabassum Mujahid, MD Norita, Samy Ganthan, Perumal Sivananthan. Advancement of a productive Timetable System, in: Proceedings of the Global Conference on control framework, figuring and Engineering, 23-25 November 2018, Malaysia.