Доклади на Българската академия на науките
Comptes rendus de l'Académie bulgare des Sciences

Tome 77, No 1, 2024

ENGINEERING SCIENCES

Automatics and informatics

AUTOMATED STATISTICAL ANALYSIS FOR IMPROVING HEIS TRAINING PERFORMANCE

Silvia Gaftandzhieva✉, Rositsa Doneva, Milen Bliznakov

Received on November 14, 2023
Presented by Ch. Roumenin, Member of BAS, on December 19, 2023

Abstract

Among the most vital key performance indicators for the quality of educational services offered by higher education institutions (HEIs) are students' retention and success rate. The number of trained students is also decisive for financing HEIs. Therefore, HEIs leaders need continuous access to data on current students in aggregated form to help them to formulate concrete and consistent, data-driven decisions to improve the quality of educational services, to attract and retain more students, and monitor the number of students. This paper offers a software tool developed for decision-making bodies in Bulgarian HEIs (deans' and rectors' management). The tool retrieves and analyses data from university information systems on students and generates aggregated reports that allow governing bodies to track the number of students at different levels (study programme, faculty, professional field) and to monitor indicators related to the accomplishment of the institutional training capacity determined by the state for admission (maximum number of students). These reports can help HEIs leaders to make timely, data-driven decisions for increasing student retention rate, determining how many admission places it can announce, and the need to change the capacity within the following accreditation procedure. Results of tool experimentation are discussed.

Key words: HEI, training, students, performance, decision-making, data analysis, management decisions

This paper is financed by the European Union-NextGenerationEU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project No. BG-RRP-2.004-0001-C01.

https://doi.org/10.7546/CRABS.2024.01.10

1. Introduction. Ensuring the high quality of education in all offered study programmes, achieving high results from the research activities of the academic staff, and the ascent of higher education institutions (HEIs) in the rating rankings are among the main goals of HEI management. In many European countries (such as Denmark, the Czech Republic, Italy, Austria, Sweden, Finland, Norway, the Netherlands, etc.), a part of the public funding of HEIs is tied to the achieved results [1]. The base indicators determining the funding are related to the achieved results in the student's training, results of the academic staff, the university infrastructure, and the quality of the services offered. In Bulgaria, each state HEI receives funds from the state budget, the amount of which is determined based on the calculated average number of students in all professional fields (PF), the grades given by the National Agency for Assessment and Accreditation, the publication of textbooks and scientific works, social and household costs and capital costs [1]. Therefore, HEI leadership should make continuous efforts to improve the quality of educational services and make management decisions that lead to an increase in the student success rate, and track the performance of a set of key performance indicators (KPI), among which the retention rate and student results [2]. To continuously monitor such KPIs, HEI is becoming increasingly dependent on the collection, storage, and automated processing of data on current students.

In recent decades, many HEIs have allocated financial resources to digitize the offered services. As a result of using such software systems, HEIs have rich data sets that enable them to track trends, provide high-level insights, and support their leaders in making management decisions. This fact increases the interest of governing bodies in seeking solutions to automate the labour-intensive process of monitoring KPI values and deploying software solutions for knowedge data extraction, enabling them to unlock valuable data insights and make informed decisions to improve ongoing processes [2].

In the literature, there are several experimental implementations of analytical tools in the HEI practices, which aim to evaluate their effectiveness to support management decision-making [3]. Provided access to aggregated data on student achievement allows governing bodies to monitor what percentage of students enrolled in the subsequent year of study, predict what part of students can drop out [4] and graduate [5]. Tracking the number of students enrolled in the subsequent year of study allows HEIs to use analytical tools for planning how many admission places it can announce. This possible application is especially crucial in countries where HEIs have institutional training capacity for admission determined by the state. Aggregated real-time information allows HEI leadership to make informed decisions about taking actions to improve the quality of education that have a positive impact on student success and aim to reduce student dropout rates [6] and increasing graduation rates [7]. By tracking the trends in the number of students and the graduation rate in the study programme in which the HEI offers training, HEI leaders can identify the most effective study programmes and those in which

they observe low results. Based on the insights, HEI leadership can undertake an in-depth investigation of the causes of poor results and make decisions to take action to improve the quality of teaching resources and the training provided in study programmes with high dropout rates and/or low graduation rates [8]. The capabilities of analytical tools for monitoring trends in data allow HEI leadership to track the effectiveness of measures taken to improve the quality of training in study programmes over some time. Another advantage of analytical tools is the ability they give to HEI leadership to track tuition revenue, return on investment and HEI management's success in achieving strategic goals [7]. Tools facilitate the generation of annual reports, reports on the HEI leadership work, and reports with aggregated data necessary for accountability to stakeholders, including external institutions [9]. HEI leadership can use aggregated data to make timely and data-based decisions on resource allocation and process quality improvement in all HEI departments [10], and to determine the effectiveness and sustainability of the initiatives undertaken to retain students and increase their success rate. In this way, HEI leadership gains insights, allowing them to measure student success. Based on the obtained insights, they can create a competitive strategy to improve the reputation of the HEI and its ascent in rating lists [10]. The comprehensive understanding of the data allows HEI leadership to identify patterns, correlations, and trends that inform strategic interventions. The experimental implementations of similar solutions in HEIs practice outline several advantages, among which the main ones stand out as automated offering of alternative solutions, reduction of opportunities for making wrong decisions and their negative impact [2], increasing the validity of the decisions made [11], a significant reduction in costs and time for discovering and analysing information for provision to external institutions or usage for decision-making in HEIs [3].

All this motivates the development of data analysis tools for decision-making bodies in Bulgarian HEIs (deans' and rectors' management – Faculty and University Management). The tool retrieves and analyses data from university information systems on current students and then generates aggregated reports and charts that allow governing bodies to track the number of active students at different levels (study programme, faculty, PF) and to monitor KPIs related to the accomplishment of the institutional training capacity determined by the state for admission (maximum number of students). These reports can help HEIs leaders to make timely, data-driven decisions for increasing student retention rate, determining how many admission places it can announce, and the need to change the capacity within the following accreditation procedure. In addition, the tool can also significantly support the preparation of current student data reports that HEI needs to send to external institutions. The developed tool is tested at the University of Plovdiv "Paisii Hilendarski".

2. Materials and methods. The development of tools for performing statistical analysis to improve the student's success rate in HEIs requires determining

the objectives of the statistical analysis and stakeholder needs, defining a set of KPIs, design and developing intuitive panels for visualizing the calculated values of the defined KPIs, providing access to the panels to all stakeholders.

The *main goal of the tool* is to enable HEI leadership to track trends in student achievement and capacity performance, identify areas of improvement and support data-driven decision-making to optimize ongoing processes and positively impact student achievement and meeting student enrolment goals. The *primary governing bodies* interested in tracking data on current students are the University Management (data for the entire university) and the Faculty Management (data for the supervised faculty).

Based on the set goals and the determined needs of the governing bodies, *seven KPIs have been defined*: number of enrolled students; % performance of capacity; % of students enrolled in the subsequent year of study; % of dropout students; % of graduated students; GPA; amount of student tuition revenue. The student information systems and the National Assessment and Accreditation Agency (NEAA) website are suitable data sources for retrieving data for forming these KPIs values. To allow data aggregation at different levels and to satisfy the needs of both stakeholder groups (University and Faculty Management), the values of all KPIs should be calculated using the different values depending on the stakeholder group. This fact, in turn, requires some of the queries to retrieve data from the data source to be parameterized by adding a "Faculty" parameter. To calculate the values of the KPI "% capacity performance" from the NEAA website, data on the capacity for the bachelor's and master's study programmes in all accredited PFs is extracted.

After a detailed study of the existing software solutions for *developing panel and reports* to visualize the calculated values of the defined set of KPIs, JasperSoft Studio and JasperReport Server were selected. When choosing the tools suitable for the set goals, the possibilities for extracting and processing data from different sources, data visualization, the intuitive interface of the tools and options for integration with external applications were taken into account. Based on the analysis of the needs of the University and Faculty management and a detailed study of potential data sources, a set of report templates is proposed, on which reports can be generated with calculated KPIs values, allowing the governing bodies to make informed decisions to take measures to increase the quality of education and retention of students. Using the JasperSoft Studio report template development tool, 27 document templates (14 for University, 5 for PF and 8 for Faculty) have been developed with elements enabling the visualization of calculated KPIs values. The data set for calculating the KPIs values is extracted in real-time after executing a request to the specified data sources (student information system and NEAA website). All templates have a Date parameter, which allows KPIs values to be calculated up to a selected date. Based on the developed templates, the user can generate reports with visualized KPIs values calculated for the entire univer-

sity, chosen PF/faculty. Therefore, some of the templates have been developed in different versions – without an additional parameter (for extracting information for the entire university) and others with additional parameters for PF and Faculty, respectively – for calculating the KPIs values for all study programmes in a chosen PF or for study programmes offered in a faculty.

Developing a software tool for the needs of HEI leadership. To ensure the possibility of report generation using the developed templates, the software tool DAASLead has been created. The tool provides central access to governing bodies to all report templates, on which governing bodies (*University and Faculty Management*) can generate documents with calculated values to continuously monitor KPIs and track progress in meeting set goals. After user authorization, the tools launch a web service that retrieves from JasperReport Server names of all templates on which the user can generate reports and their parameters. DAASLead automatically submits the value of the parameter "*Faculty*" for deans and thus eliminates the possibility of a dean of one faculty to generate reports with data for students from another faculty. Users with the *University Management* can select values for the "*Professional field*" and "*Faculty*" parameters from drop-down lists. Then, DAASLead runs a REST service to run the chosen template and generate a report. The web service interface responds to the request, JasperReport Server accesses the data source, retrieves the data needed to populate the template, performs the necessary calculations, populates the template with actual data, and generates a report that it returns as a response to the required request. DAASLead visualises the report. At the user's request, DAASLead can run a REST service to download it in PDF format. Figure 1 presents the architecture of the developed tool.

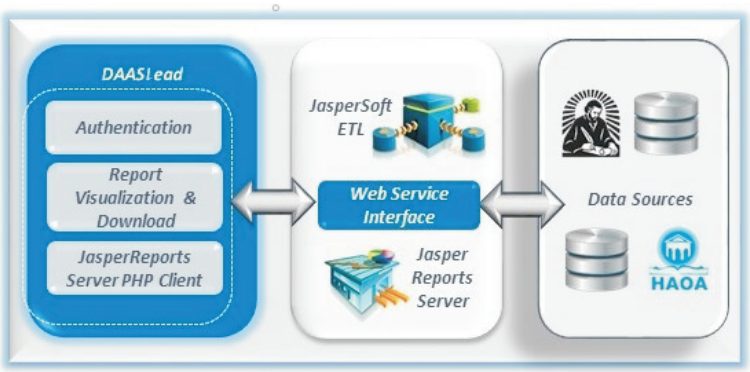


Fig. 1. DAASLead Arhitecture

Analysing the data presented in the generated reports gives the HEI leadership an idea of the current state of the university and the trends. HEI leadership can interpret the visualized statistical data to identify study programmes with high student success rates and the most attractive study programmes for students

and study programmes where they need to take measures to achieve higher results. Based on the results, the University Management can set specific, measurable, and time-limited goals for improving the quality of education in study programmes with low scores. Based on the analysed data, the University Management can make informed decisions about assigning tasks to the deans of the faculties in which there are study programmes of low interest and low success rates, identify factors that influence the results, and propose action plans that outline strategies, necessary interventions, and initiatives to enable the achievement of the set goals. The tool's real-time continuous monitoring capabilities allow HEI leadership to track progress in meeting set goals, assess the effectiveness of measures taken to improve results, and make informed decisions to adjust action plans if necessary.

3. Results. During the experiments in PU "Paisii Hilendarski", users with different roles generated reports based on the templates and evaluated the effectiveness of the proposed solution for obtaining high-level insights and guiding the univeristy strategic management.

Figure 2 presents a part of a generated report on the capacity performance of Bachelor and Master programmes by PFs. The aggregated data pinpoint a high rate of capacity performance for Bachelor programmes in 3.8 (87%) and 1.2 (85.86%) PFs and Master programmes in 1.1 (91.25%) and 1.2 (81%) PFs. In some PFs there is low percentage of capacity performance (values in red background). This result requires the managements to take measures leading to increased student interest in Bachelor's/Master's programmes in these PFs.



University of Plovdiv Paisii Hilendarski

Summary report on the capacity performance by professional fields

Date: **05.10.2023**

Professional field	Bachelor programs			Master programs		
	Number of students	Capacity	Performance %	Number of students	Capacity	Performance %
1.1. Theory and Management of Education				73	80	91.25
1.2. Pedagogy	1906	2220	85.86	972	1200	81.00
1.3. Pedagogy of Training in ...	1891	3620	52.24	796	1000	79.60
2.1. Philology	1621	2100	77.19	90	750	12.00
2.2. History and Archaeology	176	250	70.40	14	100	14.00
2.3. Philosophy	37	80	46.25			
2.4. Religion and Theology	49	80	61.25	5	20	25.00
3.1. Sociology, Anthropology and Cultural Sciences	139	600	23.17	8	200	4.00
3.2. Psychology	547	800	68.38	311	600	51.83
3.3. Political Sciences	72	150	48.00	71	90	78.89
3.4. Social Activities	111	350	31.71	50	120	41.67
3.6. Law				758	1300	58.31
3.7. Administration and Management	692	900	76.89	269	700	38.43
3.8. Economy	1305	1500	87.00	190	900	21.11
3.9. Tourism	20	240	8.33			
4.1. Physical Sciences	201	350	57.43	11	100	11.00
4.2. Chemical Sciences	234	550	42.55	49	150	32.67

Fig. 2. A part of generated report for capacity performance by professional fields

Figure 3 presents part of a generated detailed report on the capacity performance by PFs. Based on data, HEI leadership can determine the maximum number of students for admission for study for the following 2024/2025 year. For example, 1906 students are studying in Bachelor's programmes in 1.2 PF, of which 486 will complete their education in the current year. This data shows that HEI can admit the maximum number of 800 new students in this PF. The aggregated data outline PFs with a decreasing number of students. For example, there is a high percentage difference among the students studying in the Bachelor programmes in 2.4 PF during the 3rd and 4th years of study – 19 and 5 students. Clarifying the reasons for the declining number of students requires HEI leadership to generate more detailed reports with data on the success rate of students in the relevant PFs.

Detailed report on the capacity performance by professional fields

Date: **05.10.2023**

Professional field	Bachelor/Master program	Number of students by year of study						Total	Capacity	Performance %
		1	2	3	4	5	6			
1.1. Theory and Management of Education	Master	42	31	0	0	0	0	73	80	91.25
1.2. Pedagogy	Bachelor	573	437	410	486	0	0	1906	2220	85.86
1.2. Pedagogy	Master	546	426	0	0	0	0	972	1200	81.00
1.3. Pedagogy of Training in ...	Bachelor	646	489	421	335	0	0	1891	3620	52.24
1.3. Pedagogy of Training in ...	Master	564	232	0	0	0	0	796	1000	79.60
2.1. Philology	Bachelor	515	412	335	359	0	0	1621	2100	77.19
2.1. Philology	Master	54	18	6	8	4	0	90	750	12.00
2.2. History and Archaeology	Master	12	2	0	0	0	0	14	100	14.00
2.2. History and Archaeology	Bachelor	57	44	36	39	0	0	176	250	70.40
2.3. Philosophy	Bachelor	15	11	5	6	0	0	37	80	46.25
2.4. Religion and Theology	Bachelor	15	10	19	5	0	0	49	80	61.25
2.4. Religion and Theology	Master	5	0	0	0	0	0	5	20	25.00
3.1. Sociology, Anthropology and Cultural Sciences	Master	6	2	0	0	0	0	8	200	4.00
3.1. Sociology, Anthropology and Cultural Sciences	Bachelor	53	32	36	18	0	0	139	600	23.17
3.2. Psychology	Bachelor	155	170	123	99	0	0	547	800	68.38
3.2. Psychology	Master	169	142	0	0	0	0	311	600	51.83
3.3. Political Sciences	Master	36	35	0	0	0	0	71	90	78.89
3.3. Political Sciences	Bachelor	23	18	16	15	0	0	72	150	48.00

Fig. 3. A part of detailed report for capacity performance by PFs

The aggregated data in Fig. 4 shows there are study programmes with a significantly higher percentage of students who dropped out than is traditional for the study programme in some years (e.g., 13.64% of students in the Pedagogy programme dropped out in 2020). The results of the subsequent years for all study programmes are significantly lower, which shows that the management of these faculties has taken measures to lead to student retention and increase their commitment during the learning process.

4. Conclusion. The conducted experiments proved that the DAASLead tool supports governing bodies in making decisions for taking measures to retain students and increase interest in study programmes, based not only on their management experience but also on the currently calculated KPIs values. Based on the feedback from the experimental testing of the tool from representatives

Detailed report on student dropout rate (Bachelor programs) by study program

Time period: **2019 - 2023**

Faculty	Study program	Professional field	Form of study	% dropout students				
				2019	2020	2021	2022	2023
BF	Biology and English	1.3. Pedagogy of Training in ...	Full-time	16.88	7.81	0.00	3.13	11.25
BF	Biology and Chemistry	1.3. Pedagogy of Training in ...	Full-time	9.00	7.50	3.00	5.00	6.00
BF	Bioinformatics	4.3. Biological Sciences	Full-time	5.45	11.36	4.09	2.27	3.64
BF	Biology	4.3. Biological Sciences	Part-time	8.11	13.51	2.03	1.35	5.41
BF	Biology	4.3. Biological Sciences	Full-time	16.67	2.78	5.00	0.00	11.11
BF	Ecology and Environmental Protection	4.3. Biological Sciences	Part-time	8.33	11.81	2.50	2.08	5.56
BF	Ecology and Environmental Protection	4.3. Biological Sciences	Full-time	12.35	5.88	3.53	2.94	8.24
BF	Ecology of Biotechnological Productions	4.3. Biological Sciences	Full-time	0.00	0.00	0.00	25.00	0.00
BF	Medical Biology	4.3. Biological Sciences	Full-time	11.25	7.29	1.88	5.21	7.50
BF	Microbiology and Virology	4.3. Biological Sciences	Full-time	15.00	12.50	0.00	0.00	10.00
BF	Molecular Biology	4.3. Biological Sciences	Full-time	8.57	10.71	2.14	3.57	5.71
BF	Bioengineering	5.11. Biotechnologies	Full-time	30.00	0.00	0.00	0.00	20.00
BF	Pharmaceutical Biotechnologies	5.11. Biotechnologies	Full-time	9.23	7.69	3.46	3.85	6.15
PF	Primary School Pedagogy	1.2. Pedagogy	Full-time	6.92	7.69	1.15	9.62	4.62
PF	Primary School Pedagogy and Foreign Language	1.2. Pedagogy	Full-time	7.20	8.00	3.00	6.00	4.80
PF	Pedagogy	1.2. Pedagogy	Full-time	2.73	13.64	0.68	7.95	1.82
PF	Preschool and Primary School Pedagogy	1.2. Pedagogy	Part-time	1.50	5.00	3.38	13.13	1.00
PF	Preschool and Primary School Pedagogy	1.2. Pedagogy	Full-time	2.86	7.14	2.50	11.31	1.90

Fig. 4. A part of detailed report on student dropout rate (Bachelor programmes)

of different stakeholder groups, the tool's functionalities will be expanded. The next version will monitor KPIs that measure the realization of the graduates. For this purpose, templates of reports that allow visualization of their values will be designed and developed. DAASLead is part of a developed package of tools to guide the governing bodies in making informed decisions to increase the student success rate, career development, faculty staff's scientific and research activity, ensuring a higher quality of the offered training and services. DAASLead tool can be implemented in any HEI. For this purpose, it is necessary to edit the designed report templates to extract data from the student information system used in the relevant HEI.

REFERENCES

[1] EYRODICE, `https://eurydice.eacea.ec.europa.eu/bg/national-education-systems`

[2] Doneva R., S. Gaftandzhieva, M. Bliznakov, S. Bandeva (2020) Learning Analytics Software Tool Supporting Decision Making in Higher Education, IJITS, **12**, 37–46.

[3] Alyahyan E., D. Düştegör (2020) Predicting academic success in higher education: literature review and best practices, IJETHE, **17**(3), 1–21.

[4] Satyanarayana A., R. Lansiquot, C. Rosalia (2019) Using Prescriptive Data Analytics to Reduce Grading Bias and Foster Student Success, IEEE Frontiers in Education Conference, 1–5.

[5] Alshareef F., H. Alhakami, T. Alsubait, A. Baz (2020) Educational Data Mining Applications and Techniques, IJACSA, **11**, 729–734.
[6] Granados D., J. Ugalde, R. Salas, R. Torres, J. López-Gonzales (2022) Visual-Predictive Data Analysis Approach for the Academic Performance of Students from a Peruvian University, Applied Sciences, **12**(21), 11251.
[7] Zorić A. (2020) Benefits of Educational Data Mining, JIBRM, **6**, 12–16.
[8] Nguyen A., L. Gardner, D. Sheridan (2020) Data Analytics in Higher Education: An Integrated View, JISE, **31**, 61–71.
[9] Nieto Y., V. Gacía-Díaz, C. Montenegro, C. González, R. Crespo (2019) Usage of Machine Learning for Strategic Decision Making at Higher Educational Institutions, IEEE Access, **7**, 75007–75017.
[10] Klimek J., J. A. Klimek (2020) IT and data mining in decision-making in the organization. Education management in the culture of late modernity, Procedia Computer Science, **176**, 1990–1999.
[11] Borovyk M. (2020) Improving the Quality of Management Decisions Making at the Account of Using the Intellectual Recommendation System, Scientific Notes of OANU, Economics Series, **18**(46), 26–30.

University of Plovdiv "Paisii Hilendarski"
24 Tsar Asen St, 4000 Plovdiv, Bulgaria
e-mails: sissiy88@uni-plovdiv.bg, rosi@uni-plovdiv.bg, milen@uni-plovdiv.bg