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MATHEMATICS AND ENTRANCE EXAM RESULTS AS INDICATORS OF ACADEMIC SUCCESS AMONG CIVIL ENGINEERING STUDENTS

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MATHEMATICS AND ENTRANCE EXAM RESULTS AS INDICATORS OF ACADEMIC SUCCESS AMONG CIVIL ENGINEERING STUDENTS

ABSTRACT

It is crucial to select high-quality candidates for college and university enrollment, focusing on preparing them for their future careers in the shortest possible study duration while maintaining a strong graduation rate. The most reliable predictors of academic success (graduation) are observed during candidate testing (entry exams) and within the first year of study.

This paper examines the factors influencing candidate enrollment in the Civil Engineering study program, including performance in mathematics (during the first year of study), the status of enrolled students, and the completion of their studies. It also explores the relationship between the study duration and academic performance in secondary school, the entry exam results, and the ability to predict academic success—graduation.

The goals of the research were to analyze the success achieved during secondary education among SP CE students over the 12-year period, to research the success of students depending on the type of secondary school completed, qualification exam results, study status, passed mathematics courses that students study during the first academic year and to examine the possibility of using more advanced techniques for predicting the completion of studies.

Keywords: *predicting academic success, entry exam, mathematics courses, decision trees, regression analysis*

1. INTRODUCTION

All the countries of Southeast Europe face the problem of low birth rates, which is reflected in the number of secondary school students and their further education (studying). High education institutions implement many activities to interest and select the best candidates for continuing education. Selection of candidates for enrollment is very complex and demands intense and permanent work with potential candidates during their secondary education.

In the first year of the Civil Engineering first cycle study program at the Faculty of Architecture, Civil Engineering, and Geodesy of the University of Banja Luka, students undertake mathematics courses such as Analytical Geometry and Linear Algebra (AGLA), Differential and Integral Calculus 1 (DIC 1), and Differential and Integral Calculus 2 (DIC 2). The majority of students enrolled in this program typically come from gymnasiums and secondary or vocational civil engineering schools. This paper analyzes the significance of the entry (qualifying) exam for admission to the Faculty of Architecture, Civil Engineering, and Geodesy (FACEG), and examines the correlation between entry exam results and success in mathematics courses, as discussed in previous studies [1]-[5]. The impact of passing mathematics courses in forecasting the academic success of students is examined in papers [6]-[9].

This study evaluates three primary factors influencing student enrollment: secondary school performance, entry exam results, and total score. It also examines grades and the timing of mathematics exams (those taken in the first year of study), the status of enrolled students, completion of the first cycle, and the relationship between study duration and success in both secondary school and entry exams.

Advanced analytical techniques, such as decision trees, were employed to predict students' likelihood of graduation. Analysis of mathematical exam performance indicated that the timing of passing these exams (i.e., when the exam was taken and passed) is a more critical predictor of successful completion of the first cycle than the grade achieved in the exam.

Based on the completion and passing of specific mathematical exams during the current study year, the prediction accuracy for successful graduation ranges from 82.1% to 91.5%. Additionally, the prediction for successful graduation among Civil Engineering students is enhanced by generating rules derived from the data.

2. RESEARCH MODELLING

The goals of the research were:

- to research the success achieved during secondary education among SP CE students over the 12-year period,
- to research the success of students depending on the type of secondary school completed, results during the qualification exam, study status, passed mathematics courses that students study during the first academic year, and
- to examine the possibility of using more advanced techniques for predicting the completion of studies. Over a span of 12 years (from 2012, the first enrolment term, to 2023), the Civil Engineering Study Program (SP CE) enrolled or accepted transfers from other faculties, a total of 435 students.

The scoring system assigns a value of 50 points each to the secondary school score and the entry exam, with a minimum passing threshold of 15 points for the mathematics entry exam. As of the beginning of the 2023/24 academic year, there were 311 active students, and 78 students had successfully completed (graduated from) the first cycle of studies.

For the analysis and graphical representation of the data, various statistical tests were applied, including ANOVA (Analysis of variance */ANOVA/* is a statistical *test* used to assess the difference between the means of three or more groups), Independent Samples t-test (compares the means of two independent groups to determine whether the population means are significantly different), $\chi 2$ test (compares discrepancies between the expected results and the actual results), Fisher's Exact test (is used to assess the existence of statistically significant differences between the share of categories in two group variables), Kruskal-Wallis test (used to determine if there are statistically significant differences between two or more groups of an independent variable), and Mann-Whitney U test (used to test whether two sample means are equal or not).

To enhance the prediction accuracy for first-cycle completion, regression analysis and classification trees were used, which are among the most commonly applied statistical techniques for generating rules from data [10]-[12]. The analytical-statistical tool IBM SPSS Statistics, version 27, was employed for this purpose [10],[13].

3. RESULTS OF RESEARCH

Figure 1 illustrates the number of high school graduates in the Republic of Srpska from the 2012/13 to the 2021/22 academic year [14].

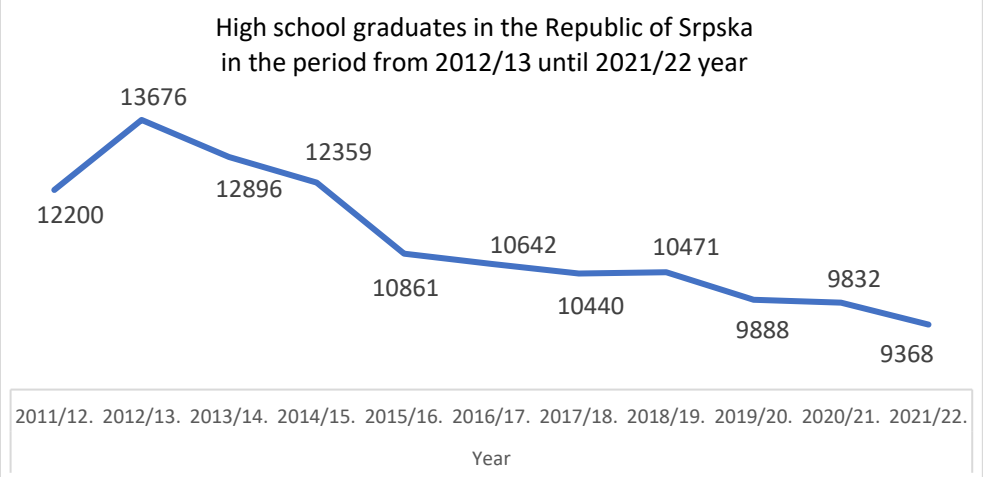

Figure 1. *High school graduates in the Republic of Srpska from the 2012/13 to the 2021/22 year*

The secondary school success scores ranged from 23.1 to 50, with the average score during secondary education being 41.68. Candidates' scores on the entry exam varied between 15 and 50 points, while the average score among enrolled students was 28.17. The total scores, which combined secondary school success and entry exam results, ranged from 38.1 to 100, with the average total score on the entry exam being 69.87.

Figure 2 illustrates the average success rates in secondary school during the entry exam and the total scores of SP CE students over the 12-year period.

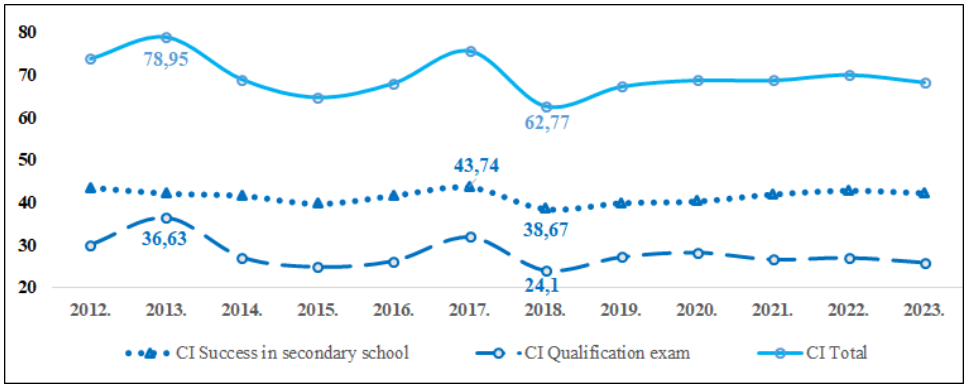

Figure 2. *Average success in secondary school, during the entry exam, and a total score of SP CE students over the 12 years*

Applying the ANOVA test, we found a statistically highly significant difference ($p = 0.008$) in the success achieved during secondary education among SP CE students over the 12-year period. Further application of the Multiple Comparisons Post Hoc test revealed a statistically significant difference ($p = 0.045$) in secondary education success between SP CE students enrolled in 2017 and those enrolled in 2018.

A statistically highly significant difference ($p = 0.000$) was also identified when applying the ANOVA test to the entry exam results of SP CE students over the 12 years. Further analysis using the Multiple Comparisons Post Hoc test showed statistically highly significant differences ($p = 0.004$; 0.000; 0.004; 0.000; 0.005; 0.000; 0.002 and 0.001) in entry exam success between students enrolled in 2013 and 2014, 2015, 2016, 2018, 2019, 2021, 2022, and 2023, respectively. Additionally, a statistically significant difference ($p = 0.019$) was observed between students enrolled in 2013 and those enrolled in 2020.

Students' secondary schools were categorized into three groups: Gymnasium, Vocational Civil Engineering Secondary School (Civ. Eng. School), and other secondary schools. By applying the ANOVA test to the data of SP CE enrollees, we identified a highly significant difference in secondary education success ($p = 0.000$) and a significant difference in entry exam performance ($p = 0.022$) among the three groups over the 12-year period, based on the type of secondary school completed.

Significant differences are noticeable in the success of candidates during their high school education and the results achieved on the entrance exam, with the best results on the entrance exam being achieved by students in 2013 and 2017.

There are noticeable differences in the success of candidates during secondary school education and the results on the professional exam, and the best results on the professional exam were achieved by students in 2013 and 2017.

The status of students enrolled up to the academic year 2019/20 (those who had the potential to graduate) is detailed in Table 1, showing that 272 students were enrolled by the 2019/20 academic year.

Table 1. *Status of students enrolled by 2019/20.*

Students' status	Secondary schools (groups)			Total
	Gymnasium	Civ. Eng. school	Other secondary schools	
active	56	57	55	168
dropped out	21	31	22	74
no status	4	16	10	30
Total	81	104	87	272

The application of the χ2 test did not reveal a statistically significant difference (χ2 = 6.513, p = 0.164) in the students' status based on the type of secondary school they completed. However, when applying the ANOVA test, a statistically highly significant difference was found (p = 0.000; 0.002) in both secondary education success and entry exam performance among SP CE students in relation to their study status. Further analysis using the Multiple Comparisons Post Hoc test indicated a statistically highly significant difference (p = 0.000; 0.002) in secondary education success between active students who dropped out and students without status, respectively.

Additionally, a statistically highly significant difference (p = 0.003) was identified in the entry exam performance between students who remained active and those who dropped out.

While investigating the status of students, no statistically significant difference was found concerning the type of high school from which they graduated. However, a highly statistically significant difference was identified in their success in high school education, their performance in the entrance exam, as well as between active students and those who dropped out or are without status.

When researching the status of students, no statistically significant difference was found regarding the type of high school completed. However, a statistically highly significant difference was observed in both high school success and entrance exam success, as well as between active students, students who stopped studying, and those without status.

The mathematics courses passed by students enrolled up to the academic year 2019/20 are detailed in Table 2.

Table 2*. Achieved marks in mathematics courses taken till 2019/20.*

Course	Mark					Mean	Total
	6	7	8	9	10		
AGLA	68	50	36	15	3	7.04	172
DIC 1	65	49	27	15	11	7.15	167
DIC 2	76	31	22	17	10	7.06	156

The period of taking the passed mathematical exams for students enrolled by 2019/20 is shown in Table 3 and Figure 3.

Table 3. *The time of taking the math exams in the period until 2019/20.*

	Exam passed				Total
	In current year	In next year	After two or more years	Not passed	
AGLA	152 (80.8%)	18 (9.6%)	2 (1.1%)	16 (8.5%)	188
DIC 1	129 (70.1%)	28 (15.2%)	10 (5.5%)	17 (9.2%)	184
DIC 2	51 (30.7%)	63 (38%)	42 (25.3%)	10 (6%)	166

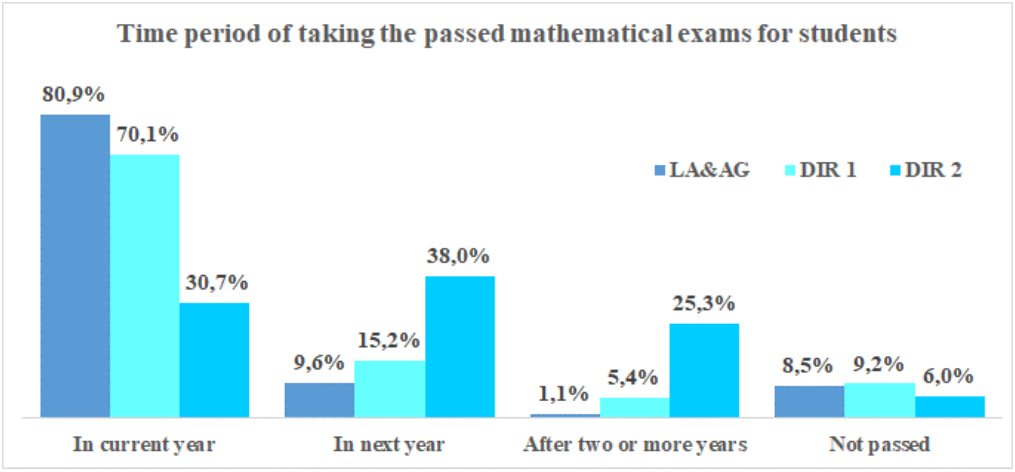

Figure 3. *The period of taking the passed mathematical exams for students*

Graduates enrolled until 2019/20 in relation to their completed secondary school are shown in Table 4.

Table 4. *Graduates enrolled until 2019/20 and completed secondary school*

Sec. school /groups/	Graduated		Total
	Yes	No	
Gymnasium	22	34	56
Construction school	31	26	57
Other secondary schools	25	30	55
Total	78	90	168

The χ^2 test was applied, and no statistically significant difference was found ($\chi^2 = 2.621$, $p = 0.270$) in the number of students who graduated versus those who did not, in relation to the type of secondary school they had previously completed.

Table 5 and Figure 4 present the average mathematics grades of both graduates and non-graduates who had enrolled by the academic year 2019/20.

Table 5. *Average mathematics grade of (non)graduates*

Graduated	Secondary school (groups)	AGLA	DIC 1	DIC 2
Yes	Gymnasium	7.50	7.95	7.73
	Civ. Eng. school	7.23	7.32	7.19
	Other secondary schools	7.32	7.44	7.72
	Total	7.33	7.54	7.51
No	Gymnasium	7.04	6.96	7.05
	Civ. Eng. school	6.79	6.47	6.32
	Other secondary schools	6.44	6.75	6.39
	Total	6.75	6.74	6.59

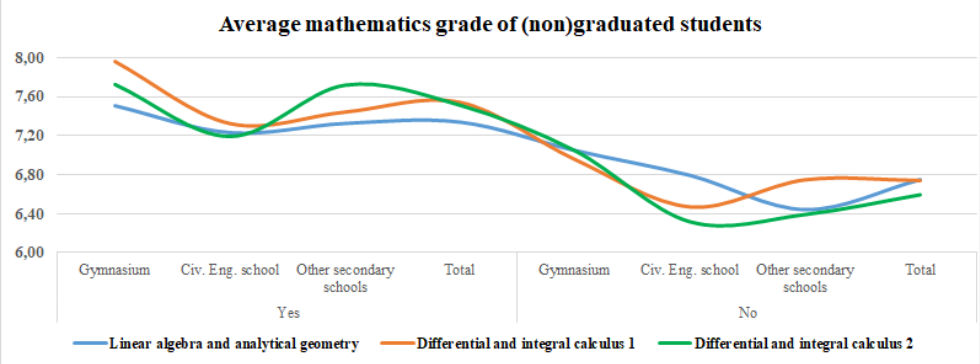

Figure 4. Average mathematics grade of (non)graduates

Table 6 shows the duration of studying (days) for students who completed the first cycle.

Table 6. *Duration of studying (days)*

Secondary school (groups)	N	Min.	Max.	Median	Mean	Std. Dev.
Gymnasium	22	1478	2923	1941.50	2016.14	402.819
Civ. Eng. school	31	1544	3427	2076.00	2190.65	496.071
Other secondary schools	25	1495	2699	1991.00	1992.44	283.030
Total	78	1478	3427	2002.50	2077.90	416.747

We did not detect a statistically significant length of study using the Kruskal Wallis Test (χ^2 = 2.368, p = 0.306) for students who graduated depending on their completed high school.

We discovered a statistically highly significant correlation between the negative prefix of the length of studying and success in secondary school (r = - 0.317) and between the positive prefix of success in secondary schools and the entry exam (r = 0.356).

Graduates, depending on the place of their secondary school (group), are shown in Table 7.

Table 7. Graduates, depending on the place of their secondary school (group)

Secondary school (groups)		Graduated		p
		Yes	No	
Gymnasium	Banja Luka	7	9	.897†
	Other cities - municipalities	15	25	
	Total	22	34	
Civ. Eng. school	Banja Luka	29	24	1.000‡
	Other cities - municipalities	2	2	
	Total	31	26	
Other secondary schools	Banja Luka	2	3	1.000‡
	Other cities - municipalities	23	27	
	Total	25	30	
Total	Banja Luka	38	36	.278†
	Other cities - municipalities	40	54	
	Total	78	90	

† χ^2 test with Yates's correction for continuity
‡ Fisher's Exact test

Applying the χ^2 test with Yates's correction for continuity and Fisher's Exact test, we did not detect statistically significant differences in the number of students who (did not) graduate in relation to the previously completed secondary school (groups) and place of secondary school graduation (groups).

In Figure 5, the achieved success in high school (left) and accomplishments during the qualifying exam (right) are shown in relation to the completion of studies (graduation).

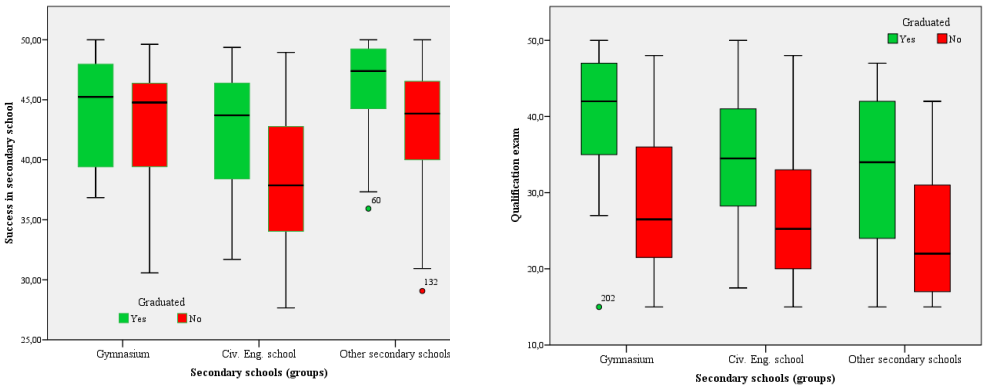

Figure 5. *Achieved success in high school and accomplishments during the qualifying exam.*

Using the Mann-Whitney test, when testing for the (non)completion of studies, a highly statistically significant difference in the achievements of grammar school students during the qualifying exam was found (p = 0.000), as well as in the achievements of students from other schools during high school education (p = 0.007) and during the qualifying exam (p =

0.004). Additionally, a statistically significant difference was observed in the achievements of construction school students during high school education (p = 0.039) and during the qualifying exam (p = 0.011).

Table 8 shows the duration of studies (in days) for students who completed the first cycle of studies, depending on their performance in mathematics-related courses.

Table 8. *The duration of studies (in days) depending on the completion of mathematics courses.*

		Duration of studies (days)				
		N	Min.	Max.	Median	Mean
AGLA - passed	In the current year	77	1478	3427	1992	2071.3
	In the following year	1	2584	2584	2584	2584
DIC 1 - passed	In the current year	73	1478	3187	1991	2033.6
	In the following year	5	2076	3427	2740	2724
DIC 2 - passed	In the current year	37	1478	2999	1908	1951
	In the following year	34	1544	3187	2045.5	2096.9
	In the next two years	7	2118	3427	2699	2655.3
Total		78	1478	3427	2002.5	2077.9

Using the Mann-Whitney U test, a highly statistically significant difference (z = -2.795, p = 0.005) was found in the duration of studies (in days) between students who passed the DIC 1 course in the current year and those who passed it in the following year.

Using the Kruskal-Wallis test, a highly statistically significant difference ($\chi 2$ = 14.115, p = 0.001) in the duration of studies (in days) was also found among students who passed the DIC 2 course in the current year, the following year, or after two or more years.

Additional application of the Mann-Whitney U test revealed:

- No statistically significant difference (z = -1.888, p = 0.059) in the duration of studies (in days) between students who passed the DIC 2 course in the current year and those who passed it in the following year.
- A highly statistically significant difference (z = -3.450, p = 0.001) in the duration of studies (in days) between students who passed the DIC 2 course in the current year and those who passed it after two or more years.
- A highly statistically significant difference (z = -2.790, p = 0.005) in the duration of studies (in days) between students who passed the DIC 2 course in the following year and those who passed it after two or more years.

A highly statistically significant difference in the duration of studies (in days) was found between students who passed the DIC 1 and DIC 2 courses in the current year and those who passed in the following year.

A highly statistically significant difference was found in the duration of studies (in days) between students who passed the courses DIC 1 and DIC 2 in the current year and those who passed them in the following year.

By examining the correlation between passing two or all three mathematics courses studied during the first year, the results indicate that students are more likely to successfully complete their studies if they pass at least two courses within the current year. Alternatively, students can pass at least one course in the current year and the second, or the second and third, in the following year or the year after (Table 9).

Table 9. *Correlation of passing of particular courses and completion of the first cycle (graduation)*

Course(s)	During the current year	Graduated	During the next year	Graduated	After two years or later	Graduated
AGLA	123	101 (82.1%)	26	20 (76.9%)	2	1 (50%)
DIC1	105	93 (88.6%)	31	20 (64.5%)	13	9 (69.2%)
DIC2	47	43 (91.5%)	50	46 (92%)	49	33 (67.3%)
AGLA & DIC1	96	87 (90.6%)	40*	26 (65%)	13**	9 (69.2%)
AGLA & DIC2	47	43 (91.5%)	50*	46 (92%)	49**	33 (67.3%)
DIC1 & DIC2	47	43 (91.5%)	50*	46 (92%)	49**	33 (67.3%)
AGLA, DIC1 & DIC2	47	43 (91.5%)	50*	46 (92%)	49**	33 (67.3%)

* at least one of the courses passed in the following year
** at least one of the courses passed after two years

Additional correlation of monitored variables is possible to find using advanced techniques. As examples, we give the application of the decision trees (Figure 6 and Figure 7).

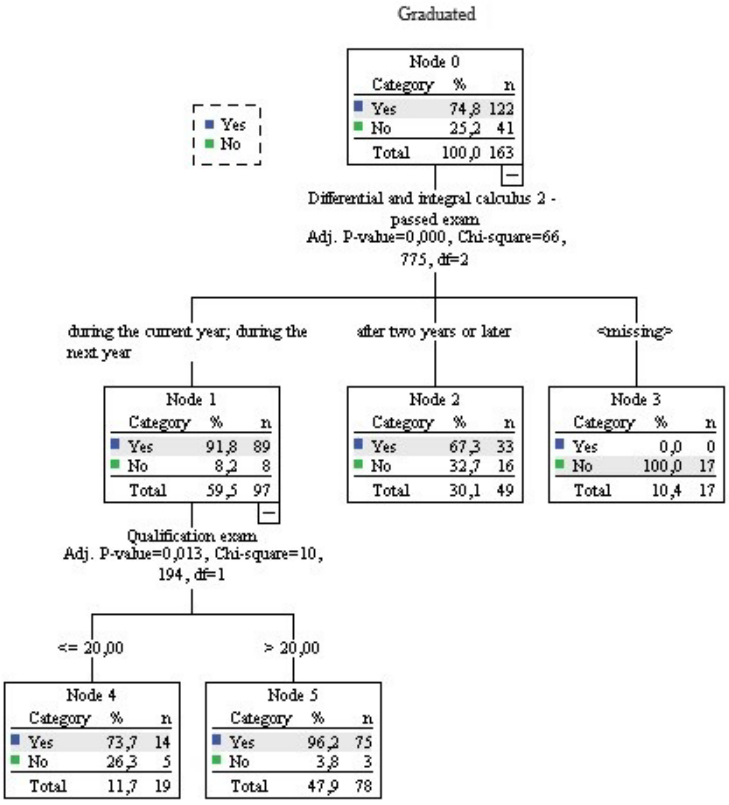

Figure 6. *Example of the decision tree*

Generated rules for three nodes are given as an example:

/ Node 4 */.*

IF (Differential and integral calculus 2 - passed exam = "during the current year" OR Differential and integral calculus 2 - passed exam = "during the next year") AND (Qualification exam NOT MISSING AND (Qualification exam <= 20))

THEN

Node = 4

Prediction = 1

Probability = 0.736842

/ Node 5 */.*

IF (Differential and integral calculus 2 - passed exam = "during the current year" OR Differential and integral calculus 2 - passed exam = "during the next year") AND (Qualification exam IS MISSING OR (Qualification exam > 20))

THEN

Node = 5

Prediction = 1

Probability = 0.961538

/ Node 2 */.*

IF (Differential and integral calculus 2 - passed exam = "after two years or later")

THEN

Node = 2

Prediction = 1

Probability = 0.673469

By forcing the variable „Entry exam“, we generated the tree (Figure 6) and rules.

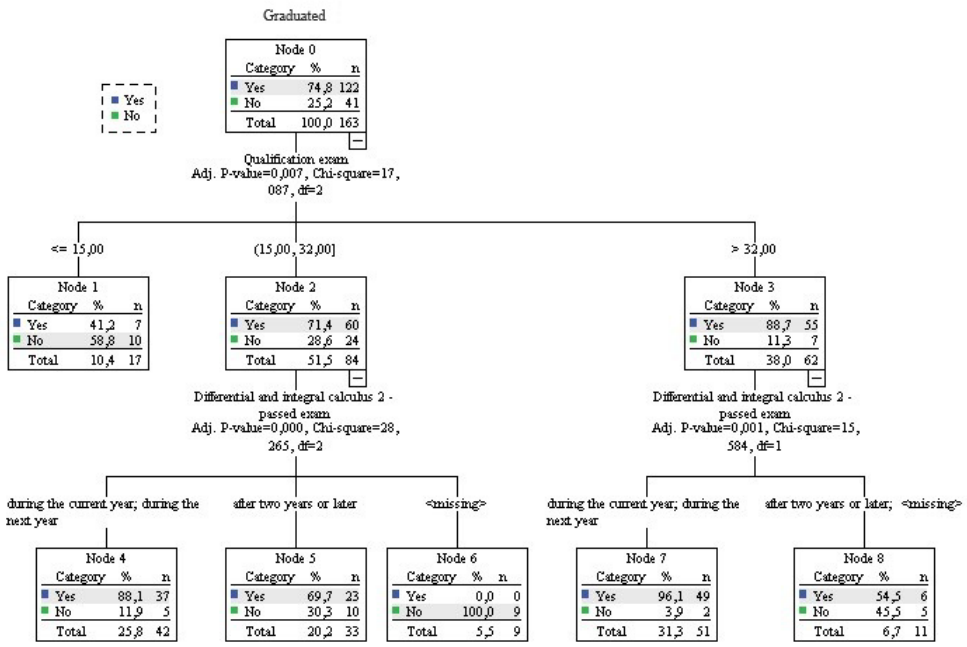

Figure 7. *Generated tree by forcing the variable „Entry exam“.*

Generated rules:

/ Node 1 */.*

IF (Qualification exam NOT MISSING AND (Qualification exam <= 15))

THEN

Node = 1

Prediction = 2

Probability = 0.588235

/ Node 4 */.*

IF (Qualification exam IS MISSING OR (Qualification exam > 15 AND Qualification exam <= 32)) AND (Differential and integral calculus 2 - passed exam = "during the current year" OR Differential and integral calculus 2 - passed exam = "during the next year")

THEN

Node = 4

Prediction = 1

Probability = 0.880952

/ Node 5 */.*

IF (Qualification exam IS MISSING OR (Qualification exam > 15 AND Qualification exam <= 32)) AND (Differential and integral calculus 2 - passed exam = "after two years or later")

THEN

Node = 5

Prediction = 1

Probability = 0.696970

/ Node 7 */.*

IF (Qualification exam NOT MISSING AND (Qualification exam > 32)) AND (Differential and integral calculus 2 - passed exam = "during the current year" OR Differential and integral calculus 2 - passed exam = "during the next year")

THEN

Node = 7

Prediction = 1

Probability = 0.960784

/ Node 8 */.*

IF (Qualification exam NOT MISSING AND (Qualification exam > 32)) AND (Differential and integral calculus 2 - passed exam != "during the current year" AND Differential and integral calculus 2 - passed exam != "during the next year")

THEN

Node = 8

Prediction = 1

Probability = 0.545455

A regression analysis for predicting the duration of studies (in days) was considered based on the timing (terms) of passing the mathematics courses LA&AG$_{tie}$, DIR1$_{tie}$, and DIR2$_{tie}$ (the index "tie" indicates the time interval of the exam). The duration of studies has the strongest positive correlation with DIC2$_{tie}$ (0.419), followed by DIC1$_{tie}$ (0,408), while the correlation with LA&AG$_{tie}$ is weak at 0.139. The positive correlation between the dependent variables was 0.398 (between LA&AG$_{tie}$ and DIC1$_{tie}$) and 0,277 (between LA&AG$_{tie}$ and DIC2$_{tie}$). The multiple correlation coefficient R is 0.498, and the coefficient of determination indicates that the regression model can explain 24.8% of the variability in the duration of studies. The coefficient of determination is different from zero (the ANOVA test yielded F = 8.122, p = 0.000), indicating the statistical validity of the regression model.

Based on these three independent variables, the regression equation was obtained:

$$\text{Duration of studies (days)} = 808.352 + 474.412 * LA\&AG_{\text{tie}}$$
$$+472.805 * DIR1_{\text{tie}} + 177.009 * DIR2_{\text{tie}}$$

4. DISCUSSION

FACEG initiated research on passing entry exams in 2012 [5] and has been implementing workshops in secondary schools that educate the civil engineering and geodesy profiles and gymnasiums for the past ten years, as well as organising preparation classes. Preparatory classes consist of 20 hours and, before the coronavirus period, were conducted in the classroom for two weeks in June. However, since the onset of the coronavirus period (in 2020) until now, they have been held online for five weeks using Google Meet and Google Classroom applications [15]. The preparation classes comprise 20 online classes (five weeks) through Google Meet and Google Classroom applications [15]. The importance of preparation classes has been recognised among the faculties in the region that organise preparatory courses and/or enable candidates to use the solved tasks from the mathematics entry exam [16-20]. The criteria for enrollment to undergraduate studies in Croatia is based on: achieved success in secondary school (400 points) and passed exams at the state prom test (Croatian language – 50, mathematics up to 450 and physics /not a condition for enrollment, but yields points/ up to 100 points); achievements at competitions – direct enrollment (1000 points)/participation in state-level competitions in mathematics and physics or winning one of the top three places in civil engineering technology/ [20].

Some faculties organise student preparation after enrollment to prepare the students for their future profession before the start of academic classes [21].

After a good selection of candidates at enrollment, it is necessary to research the influence of passing particular exams already in the first year of studying to complete studies successfully. More advanced techniques are required to predict results. The papers [22] and [23] describe creating a prediction model for students' success using Data mining and analysing the factors that influence the achieved level of success. Three methods were tested for data mining: logistical regression, decision tree and neuron nets. The Study [24] aims to provide a step-by-step guidance set for teachers ready to apply the data mining techniques to predict students' success. The successful creation of a model that has 92% correctness in predicting the students' outcome points to the potential of artificial neural nets [25]. The paper [26] analyses data on studying success and exam passing rates in the first year of undergraduate studies for eight generations of students. The goals of the research were to create a predictive model that would enable the identification of students with a high probability of not achieving 30 ECTS points during the academic year and to offer students information on the probability of passing particular exams, i.e., achieving the targeted number of ECTS points at the end of the academic year.

5. CONCLUSION

The candidates yielded solid success during secondary education (during the whole 12-year period of enrollment, the average score was 41.14), while the result of the entry exam was worse (the average score was 25.94). The total average score was 67.08.

Looking into the passing of mathematical exams, it appeared that a more important predictor of the successful completion of the first cycle of studies was the period of passing (when the exam was passed) rather than the mark obtained at the exam.

Passing particular mathematical exams during the current year of studying shows that the prediction of successful graduation is from 82.1% to 91.5%.

The prediction for the successful graduation of civil engineering students is improved by generating rules from the data.

Understanding the factors that influence students' academic success is important due to the design and content of the entrance exams and the relevance of specific academic courses for successful study completion.

It would be interesting to research the effect of individual professional courses on success in studying and duration of studies.

This research can also benefit other academic programs at universities.

6. REFERENCES

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МАТЕМАТИКА И РЕЗУЛТАТИ ПРИЈЕМНОГ ИСПИТА КАО ПОКАЗАТЕЉИ АКАДЕМСКОГ УСПЈЕХА СТУДЕНАТА ГРАЂЕВИНАРСТВА

Сажетак: Од пресудне је важности одабрати висококвалитетне кандидате за упис на факултете и универзитете, фокусирајући се на њихову припрему за будућу каријеру у најкраћем могућем трајању студирања уз одржавање високе стопе дипломирања. Најпоузданији предиктори академског успјеха (дипломирања) примјећују се током тестирања кандидата (пријемних испита) и прве године студија. У овом раду се испитују фактори који утичу на упис кандидата на студијски програм грађевинарства, укључујући успјех из математике (у току прве године студија), статус уписаних студената и завршетак студија. Истражује се и однос између трајања студија и академског успјеха у средњој школи, резултата пријемних испита и способности предвиђања академског успјеха – дипломирања. Циљеви истраживања су били: истражити успјехе постигнуте током средњег образовања међу студентима грађевинарства током 12-годишњег периода; истражити успјех студената у зависности од: врсте завршене средње школе, резултата на квалификационом испиту, статуса студирања, положених математичких предмета које студенти изучавају током прве године студија и испитати могућност коришћења напреднијих техника за предвиђање завршетка студијама.

Кључне ријечи: *предвиђање академског успјеха, пријемни испит, математички предмети, стабла одлучивања, регресиона анализа*