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Case Study: The Unified State Exam and Other Admission Tests as a Predictor of Academic Performance at the IT University

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Case Study: Using Russia's Unified State Exam and other admission metrics as a predictor of academic performance at an IT University

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1 Introduction

Innopolis University is a newly established institution in the city of Innopolis, Russia. The city was established in 2013 as a special zone with relaxed taxation for IT companies to foster the industry's development.[1] It was planned as a city with 100k+ population, which will be primarily represented by IT professionals.

Innopolis University was established by major Russian IT companies to cover a shortage of IT engineers on the Russian market. The university adheres to the Bologna process with broad adoption of best practices from partner institutions (namely, Carnegie Mellon University). English is used as a primary teaching language. As of 2015, tuition for all students is covered by grants awarded by founder companies. This grant system implies a strict selection process, with only 2.5% of applicants being admitted. At present, there are around 350 students attending the university.

The University offers programs in the fields of Software Engineering, Robotics, Big Data and Information Security. Among the offered programs, certain prerequisites are shared, e.g. basic programming, familiarity with databases and networks, etc. To provide students with these competencies, most programs share some subset of courses, which provided suitable conditions for conduction a formal analysis of student performance. On this basis, the ultimate goal is to further tailor the admissions process to the university's needs.

2 Goals of this study

In analyzing admissions data and building a prediction model of student performance, Innopolis University aims to pursue the following goals: improve efficiency of the admission process, reduce cost of tuition and increase education quality.

Increase efficiency of the admission process. Although the university has been operating only since 2014, it has an ambitious goal of general enrollment of 5k students by 2020. At the current rate of 2.5% students being admitted, this would require reviewing 40,000 student applications every year in the short time of the admissions campaign. Though IU does not envision replacing the admissions process with an automatic system, we would like to reduce the required effort by prioritizing important aspects of student applications.

Reduce cost of tuition. Low performing students require more effort from teaching staff, effectively reducing the capacity of the offered courses. Expulsion of low performers also increases the per-student cost by redistributing constant expenses to a smaller number of students. As a result of this analysis, we would like to develop a technique to effectively identify low performers in the admissions process.

Increase education quality. Increasing the general admissions quality would permit instructors to teach more advanced topics. Creating natural visibility by high level of alumni is also a high-priority concern for the university.

3 Description of the admittance process

3.1 General flow

Innopolis University conducted its admissions campaign from Feb-Aug 2015. The admissions process consisted of three main stages: an online application, on-site tests, and an interview with faculty staff.

Online application. Besides the application itself, applicants were required to pass a basic test for IT knowledge. The applicants who scored over a certain threshold were invited for on-site testing. This stage was fully automated, so the university did not incur additional expenses; for applicants, it was only about two-hour commitment.

On-site testing. This was a whole weekend event, conducted every week from May to August. On-site testing and interviews took place in Innopolis, Russia, a city 40km away from Kazan. Invited applicants were required to come to Kazan, Russia and were provided with transportation, room, and board.

Candidates were required to pass a few offline tests, including a version of the online IT test, team assignments, and a few programming assignments. All candidates were invited to the next stage; no students were rejected basing on their offline test results. The collected test scores were provided to the interviewing staff.

Interviews with faculty. These were conducted on Sunday afternoon, immediately following completion of the offline test. Typically, students passed through two rounds of 15 minutes interviews with two faculty members each. The interviewers used results of the offline tests to guide interview questions. For each student, interviewers submitted a form with evaluation of different aspects of the candidate, such as technical skills, fitness to the desired program, motivation, etc. The interview results were compared across different pairs of interviewers for consistency. Additional interviews were conducted in cases where consensus was not reached concerning a particular student.

3.2 Amendments to the general flow

- In the middle of the admissions campaign, the university introduced a requirement to submit a CV and a motivation letter with the application. Due to fairness and consistency concerns, CVs were not a criterion for invitation to on-site testing. Motivational letters and CVs were available to interviewers as a part of student files, although no uniform process for their use was established.
- In the early stages of the admissions campaign (middle of March 2015), the IT test was modified to accommodate for more questions.
- In a few exceptional cases, e.g. in case of visa issues, the university permitted interviews to be conducted remotely.

4 Available admissions metrics

From the admissions process, the following metrics are available:

- **USE grades.** The USE exam is similar to the SAT, except that in Russia it is mandatory for all high school graduates. USE includes mandatory mathematics and Russian exams and at least one subject of choice (literature, physics, chemistry, biology, geography, history, social studies, foreign language, or informatics). Each discipline is graded out of 100 points, and the results are valid for one year. However, different subjects have different passing thresholds, which are updated by Russia's Ministry of Education on a yearly basis, and for this reason, it is only appropriate to compare USE results of students from the same year for the same discipline, but not across years or disciplines.
- **Result of the online IT test.** Initially, the test included 20 questions, but one and a half months after the start of admissions, the test was updated to a new version with 40 questions. To compensate for this change,

the test result was not considered in analysis for the first 104 admitted students. In both cases, the threshold for invitation to the on-site interview was 12 correct answers. All students who scored over the threshold were treated equally.

- **School GPA.** With a large number of foreign applicants and variations of scale in Russian education, GPA scale is not uniform across applicants. Russian public school grades are issued as a whole number on a 1-5 scale, with 1 and 2 considered a fail. Russian private schools often use different scales, with the most popular ones based on 4, 10 and 100 points scale. Eight and twelve point scales are also common among applicants from former Soviet countries. For consistency purposes, only Russian public school GPAs were considered for analysis, as they account for more than 60% of records. GPA was not considered in admission decisions.
- **City of residence** is available as a raw input, sometimes with typos and invalid names. Due to non-unique names, it was possible only to extract most geographical locations from this field. City of residence was not used for the admission purposes, but it was collected to check hypothesis about higher commitment of students coming from farther places (see Section 6.3.3 for more details).
- **Source of the candidate** in marketing terms. As a part of application form, students tell where they found information about the university. This input was normalized to 18 possible sources, including major social networks, online communities, advertisement channels, offline media, etc (see Section 6.4). This information is collected for marketing purposes and was not used in admissions decisions.
- **CV and motivational letter** are also available for about 80% of the candidates. Full text of CV and ML was available to interviewing staff and explicitly used for candidates selection. However, students without CV or ML were not discriminated as requirement for these documents was introduced later in the admissions campaign. For privacy purposes, in this study we only used these documents cleaned from personal data and normalized to include only word statistics.

5 Performance data

In the Fall semester of 2015, out of over thirty offered courses offered by the Innopolis University three are included by four programs as core courses (Russian educational system does not use course numbers):

- Algorithms and Data Structures (ADS)
- Data Modelling and Databases (DMD)
- Object Oriented Programming (OOP)

Currently, there are 241 students enrolled in all of these three courses. These courses are offered by different departments, so they are taught and graded by different people. All three courses teach core IT competencies, so we might consider them as three independent sources of evaluation of technical and IT skills.

As a result of midterm evaluation and at the end of the Fall 2015 semester, students were assigned a grade on a 100-point scale. Due to different grading policies in corresponding departments, raw grades have different distributions (Figures 1, 3).

5.1 Midterm grades

To produce a single aggregated performance metric P_m, we need to compensate for the difference in grading policy. It was achieved by replacing grades with a scaled quantile function, effectively flattening the grade distribution. The sum of normalized grades was used as an individual student performance indicator, effectively producing a number in range of 0-300. The distribution of aggregate performance metric is represented in Figure 2.

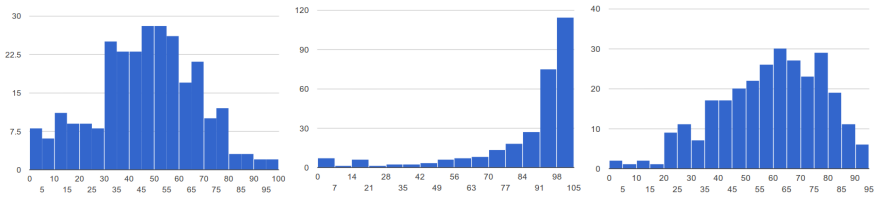

Figure 1: Midterm grades distribution, left to right: ADS, DMD, OOP

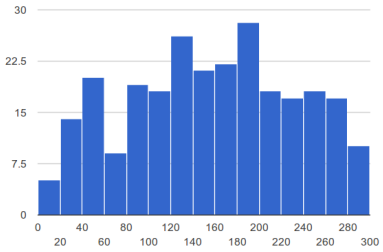

Figure 2: Distribution of midterm aggregate performance metric P_m.

5.2 Final grades

Similar to the midterm aggregate performance, we calculated final performance metric by histogram flattening and adding up course marks. The distribution of metric values can be seen in Figure 4.

6 Analysis

In the 2015 admissions campaign, Innopolis University received 20,369 online applications. Out of these applications, only 13,736 were filled in correctly and contained all necessary information. 1,027 applicants were invited for on-site interview. 738 actually visited on site interview, and 352 were admitted. Thus, the overall pass rate for a completed online applications was 2.56%.

6.1 Unified State Exam

The USE includes at least three disciplines - math, Russian, and subject of choice. Due to variation across disciplines (see section 4), we checked all three parts of the exam for predictive power independently.

To compensate for yearly variation in USE grades, we independently checked the correlation for all students and for cohorts of 2015 school graduates. For this analysis, we employed USE grades of 53 students, including 38 high school graduates of 2015.

Though the number of observations is not sufficient to make statistically significant conclusions, we can see that the correlation of USE Math and Russian grades to performance is relatively low. This observation directly supports critique of the USE exam as a singular admissions criterion in higher education.[2] Another observed pattern is a higher correlation of USE grade with final grades than midterm grades, which is also observed in the GPA analysis.

The correlation between the USE subject of choice with performance is much higher than USE Math or Russian. The majority of candidates selected Computer Science as their USE subject of choice, so a higher correlation with this exam might highlight the importance of a basic background in Computer Science for student candidates in IT education. Yet, a correlation of the USE subject of choice with performance is not sufficient to use it as a sole admission criteria; it can merely contribute to selection in combination with other metrics.

	average	standard deviation
ADS	46.0	20.6
DMD	85.5	22.9
OOP	58.3	19.4
P_m	156.7	75.7

Table 1: Midterm grades statistics

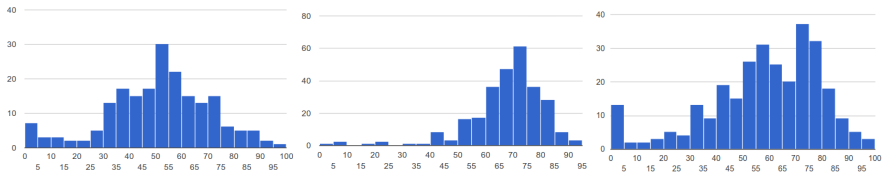

Figure 3: Final grades distribution, left to right: ADS, DMD, OOP

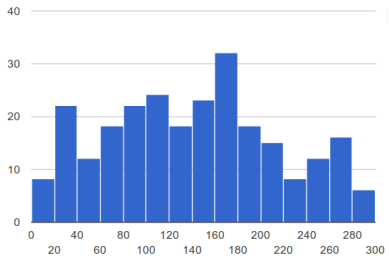

Figure 4: Distribution of final aggregate performance metric P_f.

	average	standard deviation
ADS	51.0	19.6
DMD	67.5	13.5
OOP	57.4	21.8
P_f	140.7	74.7

Table 2: Final grades statistics

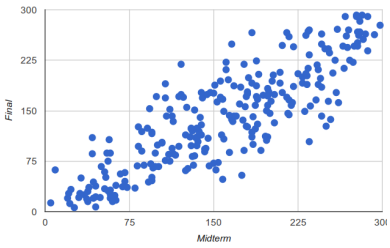

Figure 5: Scatter plot of P_m relation to P_f. Correlation of performance metrics is 0.85.

6.2 School GPA

School GPA was checked independently for recent school graduates and for all admitted students. Just as for USE grades, correlation is higher for new high school graduates. Overall, the correlation of GPA with performance is even lower than with the USE exam.

Just as with USE grades, GPA has a higher correlation with performance for new high school graduates. Also, just as with USE grades, GPA correlation with final grades is higher than with midterm grades.

	USE Math	USE Russian	USE subject of choice
P_m, cohort of 2015	0.16	0.14	0.33
P_f, cohort of 2015	0.29	0.26	0.63
P_m, all students	0.10	0.16	0.28
P_f, all students	0.23	0.29	0.56

Table 3: Correlation of USE grades with aggregate performance metric P

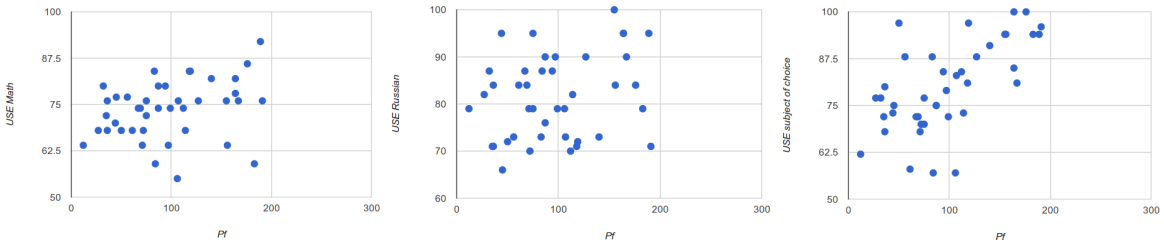

Figure 6: Scatter plot of P_f to USE grades (Y axis), left to right: USE Math, USE Russian, USE subject of choice

6.3 Demographics

Fairness in the admissions procedure is an important concern for Innopolis University. Age, gender and origin of candidates are not used for admission decisions. However, collecting this information allows the university to ensure neutrality and equal opportunities well as further improvement of the admissions process.

6.3.1 Age

Applicant age is available for over 97% of applications (i.e. 13,383 out of 13,736). Excepting groups with a small pool of candidates, all age groups demonstrate a similar performance with a group mean close to the global mean.

There is only a slight variation of pass rate to the next stage of selection across age groups. We observe only slight turbulence in age groups with a small number of candidates, namely 17 and over 28 years (see Figure 7).

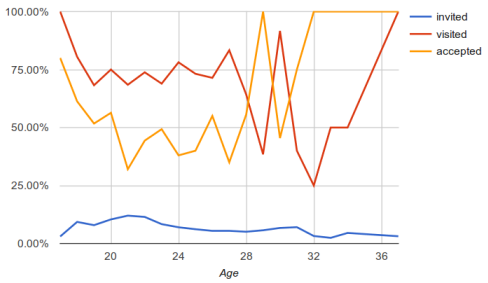

Figure 7: Pass rate to the next step of selection by age group.

6.3.2 Gender

We do not purposely collect gender as a part of admissions applications. To obtain gender statistics for analysis, we exploited an inherent property of Russian names: most Russian names are gender specific (i.e. it is nearly impossible to imagine a man named Alexandra or woman named Alexander). By making a gender dictionary for the 1000 most popular Russian names, we were able to determine gender for over 90% of applications.

Traditionally, girls in Russia are less prone to pursue IT education,[3] which explains the gap between the number of male and female applicants. Otherwise, the pass rate at each selection stage is almost equal for male and female candidates.

	GPA, new high school graduates	GPA, all students
P_m	0.24	0.17
P_f	0.37	0.20

Table 4: Correlation of school GPA to performance metrics

age	**applicants**	**invited**	**visited**	**admitted**	P_m	P_f
17	331	10	10	8	189	148
18	827	77	62	38	111	91
19	1075	85	58	30	153	130
20	1618	168	126	71	189	172
21	1557	187	128	41	192	175
22	1466	168	124	55	157	151
23	1234	103	71	35	137	137
24	915	64	50	19	111	79
25	666	41	30	12	150	156
26	514	28	20	11	182	178
27	440	24	20	7	132	96
28	276	14	9	5	94	74
29	228	13	5	5	63	17
30	179	12	11	5	45	7
31	142	10	4	3	179	171
32	124	4	1	1	N/A	N/A
33	82	2	1	1	232	262
34	44	2	1	1	30	21
over 34	1665	9	4	1	5	13

Table 5: Age statistics

For both males and females, performance metrics are within 0.3 standard deviation from the mean, which is not statistically significant for such a small number of students.

6.3.3 Geography

The applicants' geographic location was established from the optional field in admission application. Some applicants did not indicate their city of residence, and in many cases we were unable to determine geographical location due to a non-uniqueness of the city name. Overall, we were able to identify location from city in about 70% of the cases.

Candidates from Kazan demonstrate an anomalously high rate of getting invitations to on-site interview (21.4% vs 7.5% on average). At the same time, candidates from Kazan and nearby cities have slightly lower performance (about 0.2 standard deviation from mean). A lower performance of local students could possibly be explained by a lower level of commitment. Besides the attractive opportunity to go home over the weekend, failing the program for these students is less expensive as they have support of relatives living nearby.

6.4 Marketing campaign

In the admissions campaign of 2015, Innopolis University actively used online advertising, social media and email marketing. Besides that, IU attracted a significant amount of attention from traditional media after large IT companies invested in it. Besides optimizing certain marketing aspects of the admissions campaign, analyzing students' performance with regards to their application sources might lead to a better base of applicants via more informed targeting of applicants.

Intuitively, people tend to group with similar people. By placing advertisement in a community of competitive programmers, we might get better programmers than by broadcasting commercials on TV. So, by advertising in

Gender	applicants	invited	visited	admitted	P_m	P_f
Male	9952	810 (8.1%)	588 (72.6%)	290 (49.3%)	161	144
Female	2712	172 (6.3%)	122 (70.9%)	53 (43.4%)	134	125

Table 6: Gender statistics

Location	applicants	invited	visited	admitted	P_m	P_f
Kazan	891	191	149	77	141	123
cities withing 400km range from Innopolis	681	80	62	34	127	126
Moscow	1459	129	96	40	158	138
St.Peterburg	911	96	72	34	183	164
rest of Russia	5069	392	279	131	158	142
foreign applicants	1797	77	43	20	181	162

Table 7: Geography statistics

niche communities with a high-entry threshold, we might expect candidates with a richer background.

Surprisingly, we've got a significant number of applications from people referred by current university students or employees. These candidates demonstrated a higher pass rate in all stages of the selection process (e.g. 55.8% of applicants were invited to on-site interview, compared to 7.5 on average). Such an anomalous pass rate could be explained by recommenders' influence, but they also demonstrate above-average performance, which is presumably evidence of targeting effect rather than corruption. Data about marketing sources pass rate and performance can be found in Table 8.

Source	applicants	invited	visited	admitted	P_m	P_f
Online advertisement	611	611	27	16	144	115
Email marketing	203	203	12	6	126	100
Offline event	109	109	34	16	143	141
Active search in the Internet	2600	2600	101	44	171	145
Online news	183	183	10	5	87	104
TV	46	46	3	2	37	19
Word of mouth						
academia	122	122	25	11	151	129
friend (except IU affiliates)	973	973	117	50	161	156
IU student or employee	165	165	83	55	162	141
Social networks						
Facebook	271	271	6	1	N/A	N/A
VK (Russian social network)	5554	5554	168	70	157	144
other social networks	688	688	27	17	142	133
Online communities						
AIESEC	26	26	1	0	N/A	N/A
breakpointforum.ru (tech forum)	44	44	5	3	109	109
changellenge.com (entrepreneurship club)	56	56	3	1	95	116
codeforces.com (competitive programming)	43	43	9	4	220	204
habrahabr.ru (community blog about IT)	306	306	35	21	155	130
Total	13736	1027	738	352	157	141

Table 8: Marketing sources

6.5 IT test as a performance predictor

The IT test was developed by Innopolis University as a sanity check to filter out candidates without an IT background. All students with a score of 12 or higher (out of 40) were invited for on-site testing. This test was the only criterion for invitation to the on-site interview and effectively filtered out most candidates (see Table 8).

Intuitively, we might expect a higher performance from students with scores closer to 40 than those barely

passing over the threshold. However, the correlation of IT test to P_m is 0.38, and correlation to P_f is 0.43, i.e. is consistently low, accounting for the test importance. As you can see in Figure 8, the low correlation is not a result of some anomaly; they are simply not well aligned.

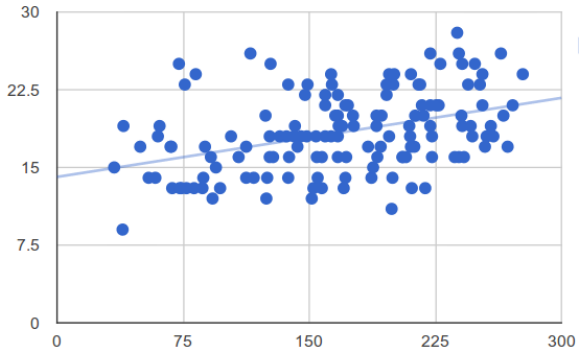

Figure 8: Scatter plot of performance metric P_m (X axis) and IT test results (Y axis).

The test was evaluated by different departments and the following issues were found:

- many questions were related to IT in general, but were not aligned with key competencies required by programs.
- a lack of questions testing key competences required by university programs
- the test readily accomodated cheating, since questions were not randomized and were publicly shared by previous applicants.

As a result, to account for all required competencies and remove unnecessary questions, it was proposed to create a new test collaboratively across all departments. Also, in the admissions campaign of 2016, IU has introduced additional offline testing before on-site interview to detect cheating.

7 Conclusion and future work

In this analysis report, we evaluated USE grades and school GPA as admissions criteria in Russian higher education. We evaluated fairness of the admissions in terms of demographics and checked suitability of the existing IT test for admission purposes.

We conclude that the predictive power of the USE exam results and school GPA is not strong enough to use them as a sole admission criteria. The influence of the school GPA and USE results is even lower for students who graduated high school over one year ago.

We did not find significant difference in performance of students of different age in range of 17 to 27 years. Also, we did not find a significant difference in performance of male and female students.

As a result of this analysis, Innopolis University reworked the IT test used at the admissions. A new test was composed with a strong involvement of all departments and passed multiple rounds of review by independent experts. The interview process was adjusted to put a stronger emphasis on motivation issues and technical background of candidates.

The biggest limitation of the analysis conducted is the small number of observations. Currently, in splitting a few hundred students according to certain aspects, we get buckets of only a few dozen people. At this rate, a few outliers in a bucket might create a visible anomaly. We hope to get a statistically significant amount of data by monitoring students performance and admission metrics over the course of 2-3 years.

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