Cognitive Work Analysis and Visualization Design for the Graduate Admission Decision Making Process

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Graduate admission has always been a complex decision making process. The link between application materials and student success has remained elusive and, as such, there is no validated method for making decisions. To understand the purposes, processes, difficulties and needs of the current graduate admission process, semi-structured interviews were conducted with participants from engineering departments. Cognitive work analysis techniques were used to summarize the findings from the interviews. Visualizations were designed to improve the current online review system. User feedback was collected in an experiment.

INTRODUCTION

Graduate admission as a decision making process has at least two major challenges: first, to enroll applicants who have enough academic preparedness and are most likely to benefit from and succeed in advanced training; and second, to enroll a diverse student body (Bleske-Rechek & Browne, 2014).

The first challenge is related to the relationship between the standard variables considered in admission and student success. This correlation is hard to learn because 1) student success has no precise definition and cannot be assessed until years after admission completes (Dawes, 1979); and 2) when considering GPA at graduate school as academic success, the data of rejected students are generally unavailable to the researchers (Dawes, 1975).

Meanwhile, the numbers of applications vary from year to year, making it hard to use the same admission criteria and policies over different years. Between 2006 and 2016, applications to U.S. graduate schools grew at an average annual rate of 5.7%, (Okahana & Zhou, 2017), which added to the time pressure on the admission work. Due to the changes in U.S. visa policy in 2017, graduate application and enrollment declined for the first time in more than a decade. This change also brought complexity and uncertainty to the control of international student enrollment in graduate schools.

Research has been done in modeling application reviewers' decision making processes (Wallace & Schwab, 1976; Moore,1998) and using the models to support decision making as filtering tools (Waters & Miikkulainen, 2013; Muratov, Lewis, Fourches, Tropsha, & Cox, 2017). However, only the numerical variables such as GPA and standardized exam scores have been included in the modeling. Similarly, although there have been calls for a holistic review approach, application decision making has remained primarily data-driven (Kent and McCarthy, 2016).

Most reviewers of graduate admissions do not have a consistent way of combining predictors and have little knowledge about of the distributional characteristics of GREs and GPAs or the validity of using GRE and GPA to predict graduate success (Dawes, 1979). Forty years after the problem was identified, graduate admissions remains a complex process where decisions are based on the personal experiences of faculty and program administrators' rules-of-thumb (Zimmermann, von Davier, & Heinimann, 2017).

In this research, semi-structured interviews and cognitive work analysis were used to understand the purposes, processes, difficulties and needs of the current graduate admission decision making process. We only considered engineering departments because these receive the largest number of applications to U.S. graduate schools (Okahana & Zhou, 2017). Admission of Ph.D. students was excluded because decision in this domain are individualized and less consistent. Based on the results of the cognitive work analysis, visualizations were designed to improve the tool for review and the decision making process.

STUDY I

Method

Semi-structured interviews and observations were conducted to collect knowledge about the cognitive work involved in the graduate admission decision making process. This study was approved by University at Buffalo (UB) Institutional Review Board (IRB).

Participants. Seven participants who had experience in graduate admission were recruited from five different engineering departments at UB. The sample included one dean's level administrator, four directors of graduate admission committees and two reviewers who served in graduate admission committees. Interviews lasted no longer than one hour. A set of questions were asked. Follow-up questions were based on participants' answers. Questions included:

- What are the main purposes of graduate admission of Masters' students?
- What is the overall process of graduate admission? What are the policies or strategies that have been practiced over recent years? How is the work distributed to the group (the admission committee)? How do they collaborate and exchange information?
- What are the main factors considered in the review of individual applications? Which of these most affect the results and how does this occur?
- If GPA is considered as a critical factor, how do you treat GPA scores from different scales? Do you convert them to a uniform scale? How do you value GPA quality from different countries, schools and majors?
- Is there any clear decision boundary set as the first step of screening? If yes, how is this boundary determined? What aspects are further reviewed if an application is sitting on the boundary?

- Which is a bigger concern, to admit a bad student or to miss a good student?

During the interview, participants mentioned drawbacks of the current electronic system they use. To investigate this issue further, an observation was conducted as follow-up with one of the participants for around one hour. The observation aimed to see how the current system functions and supports the graduate review process. The participant showed how the work is done by processing several applications while explaining the considerations and reasoning used when making the decisions.

Data analysis. Recordings of the interviews were reviewed. Notes were taken and categorized based on the following pre-determined themes:

- the purpose of graduate admission;
- the overall admission process of the associated department;
- the factors considered during the review of applications;
- whether guidelines (rules of review used over the department) were generated and used;
- whether target accept number was considered and how it was reached;
- How was diversity considered in the process?
- what was not included in the current online review system and that would be useful.

Information collected in each theme was used to generate the Abstraction Hierarchy (AH) model (Bisantz & Vicente, 1994), workflow chart and information needs prescribed by a cognitive work analysis. These are described in the results section.

Results

Abstraction Hierarchy. The AH model is shown in Figure 1. It summarizes the purpose and processes of the graduate admission process.

The first level, Functional Purpose, describes the four major goals of graduate admission: to admit students that will succeed in the program and in their future career; to hit a target number of enrollment to ensure the operation of the program; to consider the reputation of the program; and to consider the diversity of student background.

The abstract function level describes the priority of goals and the balance between the goals listed in the first level. For graduate admission, the priority is no doubt the academic performance of students. There are also constraints that need to be balanced between the goals. For example, to hit the target enrollment, the standard of student quality might be lowered and thus the reputation of the program will be affected. Diversity of students is another background goal that contributes to the program quality. There is also a time constraint that requires that work to be completed within a certain amount of time, as doing so will increase the likelihood of top student enrolling.

The third level, generalized function, describes the subprocesses of graduate admission. These are linked to the constraints concerned in each sub-process. Although there are different strategies and policies for approaching the goals, graduate admission work always includes five processes: generating a guideline for the committee members to refer to (the guideline might contain recommended criteria, strategies, and/or information based on past experience); distributing applications to individuals (randomly or based on program area of interest); individuals making decisions on applications; and making final decision on borderline applications (cases that were slightly below the expectation or had weaknesses which made decisions difficult). Apart from those, committee members sometimes exchange information and opinions. Not all the constraints in the second level are involved in every process. For example, in the individual decisions, usually only the quality of student is considered and the criteria is relatively fixed. Later, the borderline

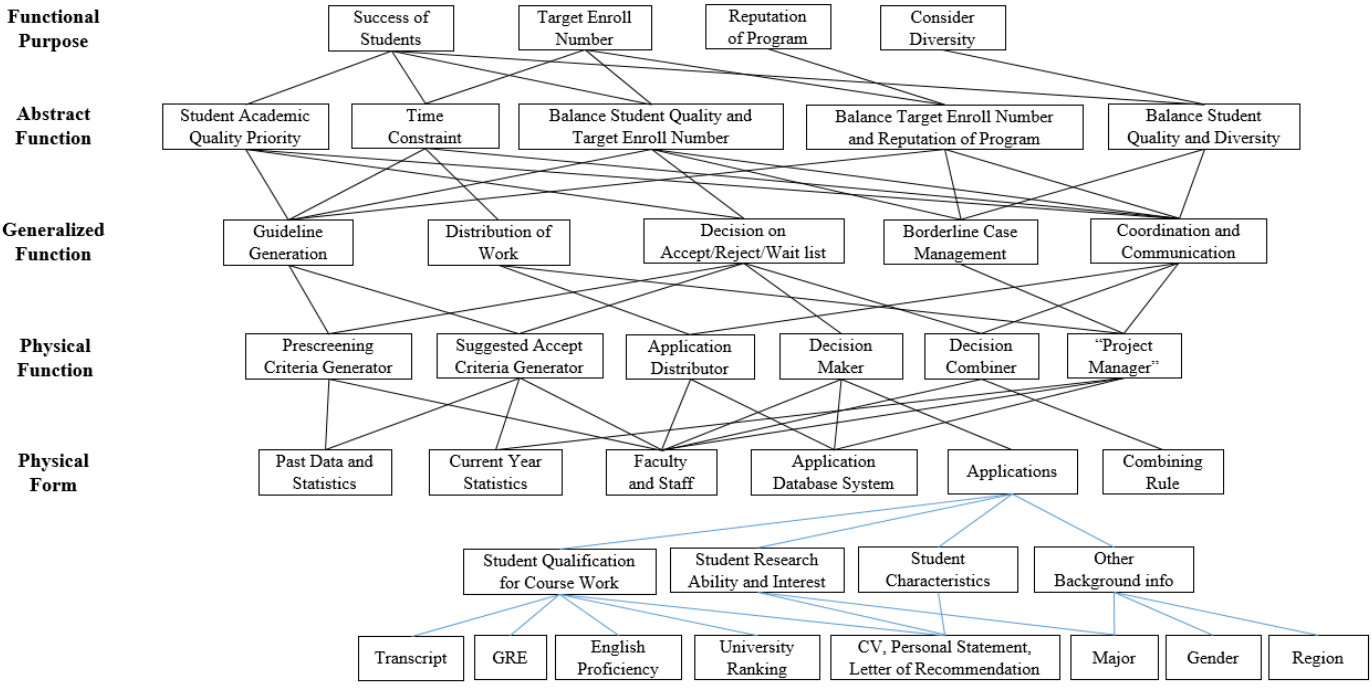

Figure 1. The Abstraction Hierarchy Model of Graduate Admission

cases are used to approximate the target number and the criteria on academic performance becomes relatively flexible. Enrolling a diverse class is also considered.

The physical function level of the abstraction hierarchy describes the physical components or equipment associated with the sub-processes identified in the third level. The physical form level describes the detailed characteristic of fourth level components. For example, the physical function "decision maker" is the function for making decisions on individual applications. It involves the physical forms of faculty and staff, who use the application database system to review applications and make decisions.

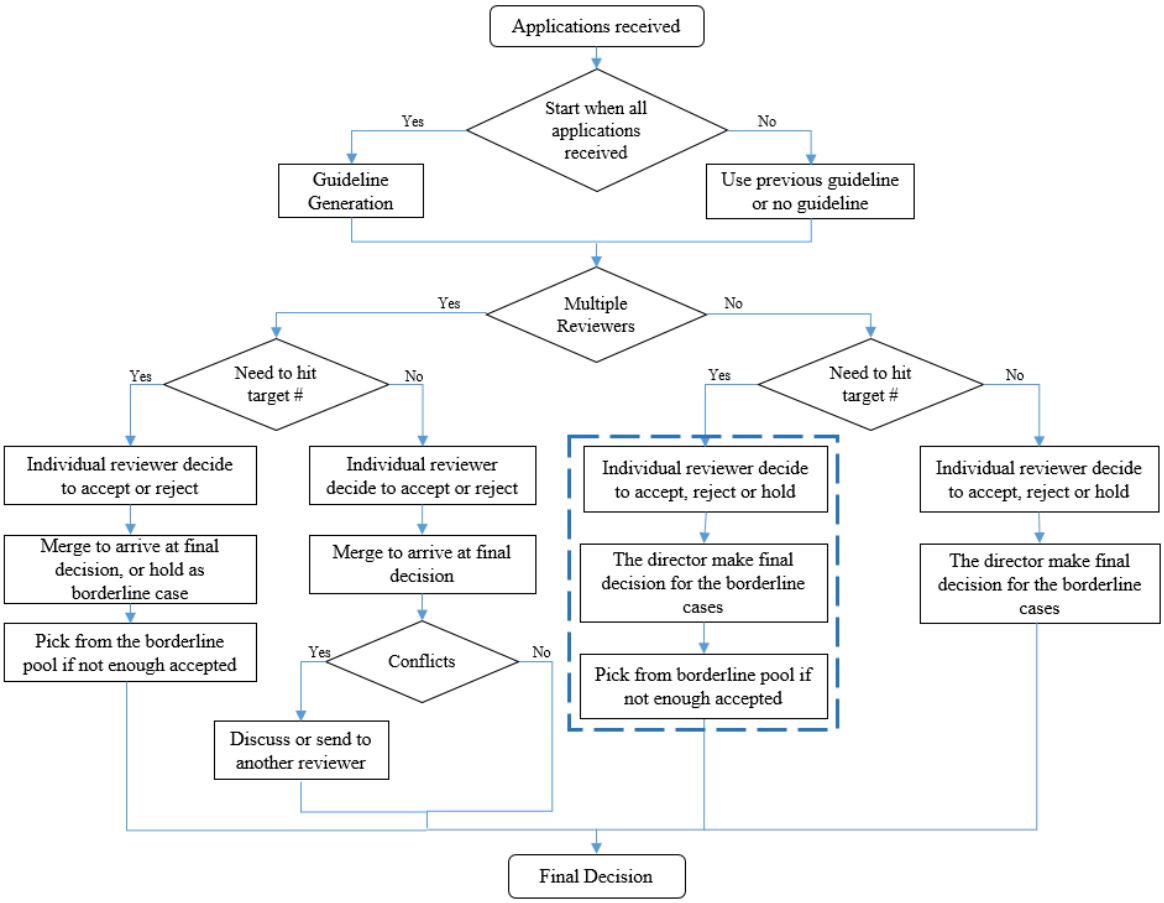

Figure 2. The Workflow Chart

The part-whole decomposition of the physical form "application" was also included. An application is usually reviewed on four aspects listed in the first level: the student's qualification for finishing the course work; research ability and interest; characteristics; and other background information. These aspects were inferred from different parts of the application, as specified in the second level.

Workflow and strategies. As mentioned above, there are different strategies and policies in different departments. Our sample covered engineering departments that were big or small, traditional or new. The following workflow chart (Figure 2) summarizes the differences in the strategies, and highlights the difficult parts of the process.

There are three branching conditions: 1) Departments may choose to start after the application deadline, which allows them to adjust their guidelines based on the full application pool; or, to accelerate the review process, they may start the process once any application is submitted. 2) Smaller departments with fewer applicants or departments with enough reviewers may use multiple reviewers. Most departments used a single reviewer for the initial review and relied on the graduate director to make final decisions. 3) For departments that had more pressure to hit a target enrollment number, they kept a borderline pool in case the number accepted was not enough.

Departments that experienced the most difficulties were the ones with large numbers of applications. If they started the process early, they lacked the big picture (total number and statistics) of the current year's application pool. These departments also used only a single reviewer per application and, in order to hit target numbers, required the director to decide on borderline cases in later stages. As shown in the dashed rectangle in Figure 2, participants reported that the most difficult part of graduate admissions was deciding on these borderline cases due to a lack of systematic criteria.

Information needs. Based on the observation of one participant, the current online review system provided the following functions: directors could distribute applications to reviewers; reviewers could see the scanned original transcript in PDF, the original GRE and TOEFL transcript in PDF; and the reviewer could render and submit decisions along with comments.

Information needs that were not fulfilled by the current system are summarized as follows:

- English proficiency was only used as pre-screening criteria. Once the score reaches an acceptable point, it no longer affects the decision. Thus, the system should reflect the rules in the department guideline (such as mark at the "cut point").
- GPA and GRE math were the main indicators of student's academic performance considered in engineering departments. New reviewers need anchors to help them make judgments about how good an application is historically or compared with the current pool. Thus, mean scores of past years and the current year should be provided for reviewers to infer the distribution of the scores.

- Undergraduate school as well as region were also important indicators for assessing GPA. Knowledge of school quality came from school ranking, faculty's personal impressions, and the performance of enrolled students who came from a given school. Some departments maintain a list of the good institutions. The review system should collect and present this type of information.
- Transcript was another important factor for assessing GPA. Some reviewers look for math courses or major-related core courses to assess the quality of the GPA. Some also look for patterns – such as whether the student performed better as he or she progressed through the program. Ideally, scores in the transcript should be grouped into math, specialized courses and other courses.
- Due to the large number of applications and time constraints, CVs, personal statements, and letters of recommendations did not play a big role in the review of Master's level applications. Some reviewers reported looking for explanations of low GPAs from the letters. The system could support more effective review by highlighting keywords in these materials.
- The undergraduate major had different effects depending on the department. Some traditional major departments had concerns regarding applicants from different undergraduate majors, while some interdisciplinary major departments welcome the unique contribution of students from diverse background. Based on the department's needs, the system might need to highlight special majors.
- Beyond application information, the overall progress of the review work could be presented to help keep track of enrollment targets. For administrative purpose, the system could show the number of applications received, reviewed and accepted. It could also show the acceptance rate of a reviewer and compare it to the overall acceptance rate with the department. Furthermore, it could show a distribution of gender of the application pool for the diversity considerations.

STUDY II

As part of a larger project, some visualizations were designed based on the information needs listed above. These were tested by participants in an experiment. This study was approved by the UB IRB.

Method

Participants. Twelve faculty members from five different engineering departments were recruited through email. Two participants had little experience in application review (only having reviewed PhD applications); eight participants were reviewers who served on their departments' graduate admission committees; two were directors of a graduate admission committee, were very familiar with the process, and authored review policies for their departments.

The experiment took around one hour. Participants were introduced to a novel decision support tool designed for graduate admission that included the visualization components created for this research. After using the tool to finish reviewing six applications, participants provided feedback on the components of the visualization design.

Result

To provide reviewers with overall progress information, three visualization components were designed as "dashboard items" to be shown on the application list page (Figures 3-5).

Figure 3 shows an example where the number of applications received (512) and processed (369) is presented with the percent of applications processed (72%), the target accept number (200), current accept number (132), and the percent of the target reached (66%). Participants gave mixed comments on this visualization. Two found it very useful to have real-time perception of overall progress. Four participants were concerned that showing the target number might bias reviewers. Participants' comments indicated that showing the upper half to all reviewers is motivating and helpful. However, they also found that the lower half was only useful to directors.

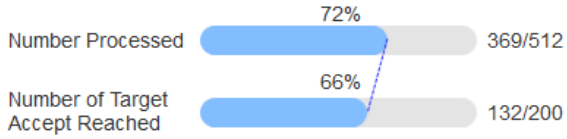

Figure 3. Visualization of the Overall Progress

Figure 4 shows a comparison of one reviewer's acceptance rate to the department's overall acceptance rate. Figure 5 visualizes the application pool of female and male, and number/percent accepted. Participants found both visualizations easy to understand but not particularly useful. This is because the acceptance rate visualization is only meaningful for departments with large application pools and because gender is typically not considered in initial decisions.

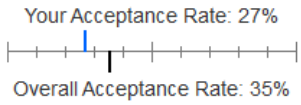

Figure 4. Visualization of the Acceptance Rate

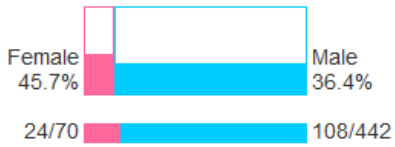

Figure 5. Visualization of the Gender Distribution

To provide reviewers with some statistics about the application pool, two visualization components were designed to be shown on individual application pages (Figure 6 & 7).

Figure 6 shows the visualization of the GPA and standard exam scores. The bar length visualizes the applicant's score. The dashed lines mark the past accepted applicants' average score, current year applicants' average score, and suggested "cut points" (the numbers associated with these lines are shown when hovering over the bars with a mouse cursor). This visualization provides participants with the distribution information of the application pool. Two participants found the cut point confusing. One participant commented that the "hover over" is

not convenient without using the mouse. One participant suggested that more statistics such as max and min be added.

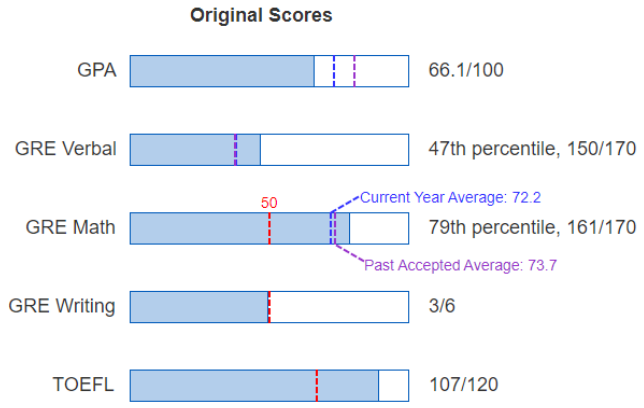

Figure 6. Visualization of the Exam Scores

Figure 7 shows an example of a radar chart that is used to visualize the percentiles of the applicant's scores compared with all of the current year's applicants. This example shows a 50% percentile on GRE math. This means that the applicant's GRE math is better than 50% of the current year's applicants. A larger triangle shows better scores.

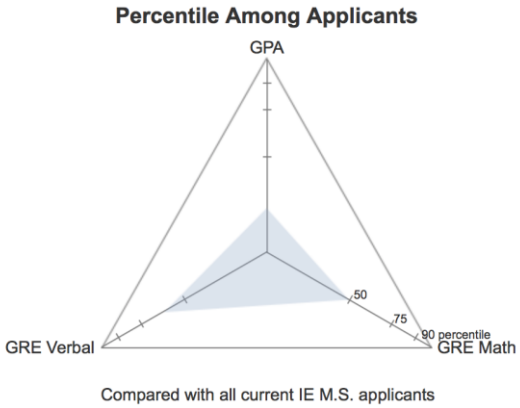

Figure 7. Visualization of the Score Percentiles

Seven participants found this visualization very useful, because "it is good to see the whole condition in one sight". Participants also commented that it might be useful for quick screening and comparing the borderline cases. Two participants found the percentiles of GRE scores (among current year's applicants) confusing because the original GRE scores were also given by percentiles (among the test takers). This could potentially be improved by adding "better than % of the applicants" to the title.

DISCUSSION

This research focused on understanding the purposes, processes, difficulties and needs in the graduate admission decision making process of engineering departments.

Findings from the current research were similar to the themes identified through interviews and literature review conducted by the Educational Testing Service (Payne, 2017; Michel, Belur, Naemi, & Kell, 2019): the graduate admission process is decentralized – decisions are made by department-level committees rather than the campus-wide admissions office. There were general goals and processes shared by the departments, but the specific goals and strategies varied based on the department's own condition.

Due to the volume of applications and shortage of reviewers, the decisions relied mainly on the GPA and standardized test scores. Specifically, GRE math was used as an important indicator in engineering departments. Undergraduate school and region were factors associated with the quality of the GPA. The other admission materials, such as transcripts and letters of recommendation were used on the decisions of borderline cases, but their use was highly subjective and not standardized.

Some departments provided guidelines that instruct reviewers on the "suggested accept/reject score", but some department left the decision solely to the judgement of individual reviewers. Therefore, it is important to provide context (distribution and statistics of the application pool) for the scores to support reviewers' evaluation and judgment on the scores. Of the whole admission process, decisions on the borderline cases was reported to the most difficult.

Visualizations were designed to fulfill some of the information needs identified from the interviews. Participants' feedback showed that the visualizations were easy to understand, and could potentially help the decisions.

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