

Making a Pecan Pie: Understanding and Supporting The Holistic Review Process in Admissions

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Holistic reviews are a common practice employed by colleges in the United States to make admissions decisions. It is an individualized review process where reviewers assess an applicant's potential by considering various criteria including academic metrics, adversities faced, and personal attributes. While the factors considered in such reviews are broadly known, a detailed walk-through of the process is absent in the existing literature. This is important to understand what is done in practice and to identify opportunities for technological interventions to support the complex and changing process. We employed cognitive task analysis and a socio-organizational approach to understand the holistic review process at a highly-selective, private university. We found the process to be nuanced and complex owing its complexity both to the numerous variables involved and the reviewers' thought processes. We present a rigorous, structured characterization of the review process and suggest possible leverage points for applying visualization decision-support tools.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**;

Additional Key Words and Phrases: Holistic college admissions; cognitive bias; decision making; information visualization;

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1 INTRODUCTION

“My boy, you’ve got to know the shape of the river perfectly. It is all there is left to steer by on a very dark night.”

—Mark Twain, *Life on the Mississippi*

Bowen and Bok use Mark Twain's "the shape of the river" analogy above in their book of the same name to describe the complexity of the college admissions process in the United States of America [9]. To navigate and understand the admissions process, one must understand the numerous variables, features, caveats, and policies that the process involves which is akin to the knowing all the shape variations of the ~1,200-mile-river.

The undergraduate college admissions process is central to the progress of the country and has significant social, economic, and political implications. It has been a topic of continual and consequential debate for many decades now. Even recently, Harvard University has come under

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the scrutiny of the Justice Department on the grounds of discrimination in admissions [11]. A good deal of such debate and unrest stem from colleges and universities' lack of transparency in their admissions policies and practices.

Additionally, the dynamics of undergraduate admissions are changing in universities and colleges throughout the country. Generally speaking, these changes include an increase in the number of applications, more diversity in the demographic composition of applicants, increased cost of higher education, and a decrease in students' ability to pay for undergraduate tuition [36]. Colleges are forced to take into account and adapt their admissions policies to these changes. Adapting to these changes may require changing their decision-making strategies and finding ways to expedite the process without compromising quality.

There is a need, especially at this present time, to address issues of transparency and make what is known about admissions processes reflect what is done in practice. Understanding the processes through observations and interviews can not only enhance transparency but also help in identifying opportunities for technological interventions. These interventions can assist colleges in adapting to the shifting dynamics and also improve their review processes. This paper presents first steps in these directions.

The admissions process is typically non-trivial, hard to characterize, and mainly, varies from college to college. Broadly speaking, admissions processes at colleges can be distinguished based on three aspects: (i) selectivity (ranging from all-inclusive to highly-selective), (ii) type of review (ranging from largely objective to subjective or holistic reviews), and (iii) College missions and enrollment goals [28, 36].

Holistic reviews are generally complex and subjective in nature. Admissions officers review every application in *context* [28] by considering factors such as the applicant's high school, family background, adversities faced, grade trends, non-academic accomplishments and personal qualities of the applicant. Non-academic aspects may include community service, music ability, special talents, and leadership skills.

We were interested in studying how admissions officers collectively make undergraduate admissions recommendations at a highly-selective, private university that employs a holistic review process. Understanding the collective process also required understanding its constituent individual contributions. In particular, we were interested in studying the individual officers' knowledge and application-review activities, i.e. *awareness* [17], and the distribution of applications among the officers for review purposes and their coordination, i.e. *articulation work* [39], which are forerunners to the cooperative, collaborative work setting.

In this paper, we employed cognitive task analysis (CTA) and a socio-organizational approach to characterize how the admissions officers individually and collectively review applications at this university. We collected data by conducting situated interviews and observations. We present a rigorous, structured characterization of the process and suggest leverage points within the characterization where visualization decision-support tools might be applied.

To the best of our knowledge, this is a largely unexplored area in Computer-Supported Cooperative Work (CSCW) and Human-Computer Interaction (HCI). The primary goal of the work presented is to provide a descriptive account of the application-review process at this university resulting from our observations and interviews. While we provide implications for visualization design (in form of *leverage points* which more naturally follow CTA approaches [38]), our characterizations do not encompass the gathering of any specific design requirements [15]. As such, they can be solely used to gain a better understanding of the process and also enable others to see alternative approaches and ideas for technological innovation.

2 BACKGROUND

We discuss a few examples of the myriad studies available on undergraduate admissions in the United States and then present the foundational aspects of holistic reviews and demonstrate why they can be challenging.

2.1 Literature on Admissions

There are many studies concerning admissions processes in the United States and they have provided us with the much-needed sociological underpinnings to understand the process. The materials we referred to include sociological research articles and books, popular nonfiction books, news articles, and numerous online blogs, and Opinion Editorials (Op-eds).

The College Board documents [1, 36] are some of the earliest documents which present a taxonomy of the various decision-making models in present-day admissions and list the factors generally considered in holistic reviews. These documents were results of College Board meetings involving approximately 50 admissions directors, deans and researchers from various colleges in the United States. Jerome Lucido, who contributed to the College Board documents, elaborates on the above taxonomy and the implications of various factors in admissions decisions in his article [28]. These articles were aimed at communicating to the public how and why admissions decisions are made as well as to create foundational material to spur future discussions on admissions.

Significant research in higher-education and sociology domains has been conducted to study the pros and cons of various admissions policies which serve to inform the practices employed in colleges [8–10]. For example, Bowen and Bok champion affirmative action and provide empirical evidence proving the effectiveness of race-sensitive policies [9]. Camara and Schmidt found significant differences in standardized-test performances between ethnic and racial groups which were largely explained by the differing socio-economic statuses between the groups [10].

Popular single-author nonfiction books, such as Jacques Steinberg's *The Gatekeepers* [43] and Daniel Golden's *The Price of Admissions* [20], have been written for the public interest and attempt to demystify the admissions black box. They report various debatable admissions practices in certain universities and employ a sensational writing style. Jacques Steinberg writes about his observations of the admissions process at Wesleyan University for almost one year in his book, *The Gatekeepers* [43] and Daniel Golden's *The Price of Admissions* [20] is the result of two years' worth of investigative journalism and interviews with several people including students and admissions officers.

There are many online blogs and articles to inform potential applicants and also the general public of how admissions decisions are made in various colleges. Some of these articles are written by people working in admissions themselves. Examples include the Vanderbilt admissions blog [4] and the now-archived *The Choice* blog by NYTimes [3].

As we can see, the details on how admissions decisions are made are scattered across many resources. The considerations for admission specific to a university and a structured walk-through of its application-review process, as done in this paper, is lacking in existing literature. While all of these resources are concerned with the social aspects of the process, we are also interested in studying the process from a technological standpoint. The reviewers are our user population of interest and we identify opportunities to support their decision making through the use of information visualization tools. We indicate the areas addressable by visualization tools within our characterization of the review process.

2.2 Holistic Review Process: Importance and Complexity

B.A. Thresher states in his 1966 book, *College Admissions and the Public Interest*, that "the process of admission to college is more sociologically than intellectually determined" [46](p. 1) and this largely holds even today [28]. Students from high-income families are generally provided with more opportunities and high-quality academic preparation. Studies have shown that there is a strong positive correlation between students' test scores and the socioeconomic statuses of their families [10]. Students from low-income families, on the other hand, may receive inadequate academic training and may go through additional hardships as a result of trying to make ends meet. When students with such diverse backgrounds, different talents, dissimilar experiences, and disproportionate family incomes contend to attend the same college, how are admissions decisions made? Specifically, how are admissions decisions made that uphold American egalitarian notions, provide equitable opportunity, and promote upward mobility?

Defining *merit* becomes non-trivial in these scenarios and objective measures such as test scores and high-school GPAs alone cannot be used to judge students' capabilities. For example, a student from a moderately affluent family who ranks in the top 5% of his class can be said to have merit and the same can be said of a student who ranks in the top 15% of her class and is a first-generation student. Evaluating applications would then require considering every application individually and assessing the applicant's accomplishments and performance in relation to the opportunities presented to the applicant [28]. The holistic review process intrinsically embodies this practice and endeavors to provide a just means to make admissions decisions.

While objective reviews would be far from fair, true holistic reviews are hard to implement in practice. Since every application presents a unique case, the downside to holistic reviews is the lack of a definite solution path and hence a systematic and uniform review method. The holistic review processes employed in colleges are not arbitrary, however, and the reviewers are usually guided by policies that draw on the college's mission and goals in their decision making. As a result, there are predetermined attributes the reviewers look for in the applications but the interpretations of many of these attributes and the associations made depend on the discretion of individual reviewers. Additionally, some of the attributes considered may not predict an applicant's competence or some attributes may be given undue consideration in the review process. Hence this trade-off, while still retains contextualizing applicants, may also result in differing practices among colleges and inconsistently-subjective reviews within colleges.

The differing practices result from differing college missions and enrollment goals for constructing the incoming class which depend on several factors including the college's funding type, i.e. public or private, the educational programs offered and its societal role [28]. One of the admissions officers we interviewed remarked,

"[This university] has been asked to make a pecan pie. [A different university] cares about making a pumpkin pie. Every university has its own priorities and concerns."

3 METHOD

Holistic reviews can be defined as *complex* tasks performed by reviewers who are *subject-matter experts* (SMEs) [12]. Complex tasks require the use of both conscious and automated knowledge of experienced SMEs in performing tasks that can persist for many hours or days [12]. Therefore, to understand how the reviewers evaluate applications and make recommendations, we decided to *elicit* their cognitive processes and knowledge underlying their task performance.

As outlined by Clark et al. [12], we proceeded by collecting preliminary knowledge about the application-review process at the university through document analysis (as described in Section 2) and an informal discussion with a senior member at the admissions department. We then identified

the tasks of interest in the review process and the knowledge-elicitation methods to apply to them. We used (i) a process-tracing technique [13], which is a type of cognitive task analysis (CTA), to capture the reviewers' cognitive processes when reviewing applications, both individually and collectively and (ii) a socio-organizational approach to characterize the reviewers' roles and requirements within the university and admissions context. These complementary approaches were used to fully understand and organize our knowledge about the review process.

3.1 Preliminary-knowledge collection

We began by collecting a wide variety of admissions-related resources to familiarize ourselves with the problem domain as described in Section 2 and we referred to these resources throughout our study. We then conducted an informal discussion with a senior member at the admissions department at the university prior to conducting our study. This discussion gave us a very high-level view of the admissions process and helped us structure our study. The university receives approximately 20,000 applications for undergraduate study every year and has an acceptance rate of less than 20%. The review process at this university is very similar to the process described in Case #1 (p. 17) of the College Board report [1] and we briefly describe it below.

The reviewers evaluate applications from the geographic areas assigned to them. A portion of the applications also receive second reviews by different reviewers. Committee meetings take place after all the individual reviews of applications have been completed and are where most of the previously-reviewed applications are discussed and recommendations are made on undecided applications. Reviewers present applications from their geographic areas during the meetings and the committee discusses these applications. The last stage of the process involves viewing the incoming class as a whole and ensuring that it is right-sized and well-rounded as well as *well-lopsided*. Well-lopsided refers to demonstrating excellence in particular activities as opposed to all-round excellence.

3.2 Data Collection and Analysis

3.2.1 Cognitive Task Analysis. We identified the individual application reviews and the collective reviews during committee meetings to be the focus of our CTA. We used the CTA method of *process tracing* to observe and collect *verbal reports* [13] from the reviewers as they concurrently reviewed applications both individually and collectively during committee meetings.

Process tracing through a think-aloud protocol can be used to capture the combined *declarative* and *procedural* knowledge underlying experts' task performance. SMEs typically combine their declarative (or conscious or conceptual) and procedural (or unconscious or automated) knowledge in performing complex tasks [12]. While they can reasonably articulate their declarative knowledge when methods employing *recall* are used, they cannot consciously recall or articulate their procedural knowledge which, however, can be "elicited" via think-aloud in process tracing.

We used our observation notes and the collected reviewers' verbal reports to make inferences about the (i) the various application attributes considered and the cognitive processes of the reviewers associated with them during individual reviews, (ii) the distributed cognition during committee meetings involving the presentation and discussion of applications, and (iii) the *materialities* of the representations of applications and reviewers' evaluation records. Materialities refer to the properties of information representations which influence and shape the processes in which they are used [16, 34].

3.2.2 Socio-organizational approach. We were also interested in learning about the potential factors contributing to the reviewers' experience and knowledge they apply in evaluating applications. Hence we also conducted semi-structured interviews as part of the socio-organizational

approach [14] (p. 450-474) to understand the role of our stakeholders, i.e. reviewers within their organizational context and to identify their requirements by querying them about their activities in the admissions process and the challenges they face.

3.2.3 Data collection. We collected information for analysis using observations and interviews to uncover as much detail about the process and reviewer behavior as possible. We conducted semi-structured interviews with four reviewers followed by observations of each of them reviewing a sample application using a think-aloud protocol. We also passively observed roughly 2 hours of a mock committee meeting session.

Since the admissions officers were concerned about the collection of identifying information and also due to the sensitivity of the information being collected, we only recorded notes (typed on laptops) during both interviews and observations and no audio/video was recorded. Given these limitations, we focused only on the tasks of interest and did not take notes of deep data such as the times for each remark in their conversations or gaze behavior. During the observation sessions, we, a group of three researchers, collectively recorded both their verbal reports *verbatim* and our observations of how they performed the tasks. During the interviews, we recorded our understandings and interpretations of their responses [21].

In addition to the data collected, we also referred to external documentation, such as the Common Application [2], which served as supporting material to understand the reviewer tasks and their interactions with the current software used for reviewing applications.

3.2.4 Data analysis and verification. We coded the data collected through the observations and verbal reports to build the task decompositions of the individual review process and the committee-meeting-proceedings and summarize the associated reviewers' cognitive processes. We presented the resulting characterizations to the admissions officers for them to verify the accuracy of the recorded application attributes and corresponding cognitive actions and made revisions based on their feedback. We used Affinity Diagramming [21] to organize the information collected from the interviews pertaining to the socio-organizational aspects of reviewer roles and requirements.

3.2.5 Formatting CTA results. There can be various end goals of CTA, such as to build documents for training purposes or to transfer the expertise elicited to other tasks, and depending on the goal, the CTA results are formatted accordingly to present, for example, decision-making models or detailed descriptions of all the necessary actions to perform a task [12].

Our goal in performing the CTA, however, was to generate a descriptive report to provide a thorough understanding of the application-review process and make apparent opportunities for supporting the process through technological interventions. To this end, we present our CTA results in the format of structured characterizations of the process outlining the various application attributes, the cognitive tasks reviewers perform with respect to each of them, and the *material* properties of the software artifacts currently used in the review process. These characterizations helped us understand the current practices, identify their drawbacks, and suggest potential leverage points for applying visualization tools.

3.3 Procedure

Following approval from the Institutional Review Board, we contacted admissions officers who reviewed incoming applications for undergraduate admissions at this university. We contacted them by an e-mail describing the study. All the interviews and observations were conducted in the workplace of the reviewers and with the desktop systems they currently use for reviewing applications. After they signed the consent form, they were first interviewed where we asked them to elaborate on their roles and responsibilities and the challenges (both specific to them and

general) in the admissions process. We also asked them about the tools and software they used while reviewing applications.

Following the interviews, we observed them while they reviewed a sample application. The reviewers were asked to think-aloud and state the application attributes they were looking at, their associated thought processes, how and what notes they recorded and the rationales for their recommendations. We asked them clarification questions during and post observation. The individual interviews and observations each lasted between 30 minutes to an hour.

Five admissions officers were present and roughly 16 applications were presented and discussed during the mock committee meeting session we observed. We observed how and what materials and tools presenters used to summarize an application, the activities of the non-presenting members in the committee and how the members discussed the applications. Following the observation, we asked them clarification questions. Our data collection was intermixed with analysis and we used the data collected in the initial interviews to formulate new questions and refine our focus for the later ones.

3.4 Participants

We did not collect the age and gender information of the reviewers who took part in our study. Most of the reviewers are the university's alumni and hence they better understand the university's mission and what it stands for. Their experiences as reviewers ranged from 1 year to more than 30 years. We compensated each of the reviewers we interviewed with a \$50 gift card for participating in our study.

4 FINDINGS AND CHARACTERIZATIONS

We present our contributions slightly unconventionally. We begin by presenting the themes organizing reviewer roles and requirements in the process. We then prematurely discuss our key findings and leverage points identified for applying visualization tools. This is done so that we could make suggestions for visualization techniques in multiple places within the characterizations of the review process discussed later. We use the terms reviewers and admissions officers interchangeably throughout and numbered headings denote sequence/order of events.

4.1 Reviewer roles and requirements

We focus on the reviewers here – their roles, activities, and the challenges they face during the admissions process. The themes presented help us understand the big picture and how the various components are interlinked in the admissions process. For instance, we learned that a large part of the background knowledge that reviewers use in making recommendations during application reviews is derived from their visits to high schools, prior to the institution's receiving of applications.

4.1.1 Geographic areas. Reviewers are assigned non-overlapping geographic areas or territories within and/or outside the US. They are each responsible for reviewing the applications received from their respective areas. The reviewers generally have first-hand knowledge about the high schools in their geographic area and their comments for an application from their area are weighted more heavily than the comments from second reviewers who are generally not familiar with the area.

4.1.2 Travel, Recruitment, and Yield. The admissions process, from a reviewer's perspective, can be seen as consisting of three seasons - travel or recruitment season, reviewing applications, and lastly, the "yield" season.

Reviewers visit high schools in their geographic areas during September, October, and part of November. Reviewers find travelling interesting and consider it as "research." They find meaningful

insights about the school contexts, economic statuses of the students, and opportunities provided to the students which they use to evaluate applications. They also interact with students during these visits and they often remember certain students they've interacted with when reviewing their applications later on.

Reviewers also act as recruiters and try to get the best students in their area to apply to the university. This is done by the reviewers consulting high-school databases as well as through contacts from the individual schools.

Post-application-reviews, i.e. the "yield" season, reviewers interact with potential incoming students and invite students to visit the university campus.

4.1.3 Reviewer Challenges.

- *Extra hours of work:* One of the main challenges that the reviewers face is the sheer volume of the applications and the limited time to review them. This challenge often results in the reviewers putting in extra hours of work. The reviewers each review between 1000-2000 applications in a time period of roughly 4 months. Reviewers are also subject to "interruptions" while reviewing applications, such as receiving numerous emails from applicants or people associated with the applicants and these interruptions prolong their application reviews.
- *Demands of holistic reviews:* The very nature of holistic reviews adds a considerable burden on the reviewers. These reviews entail looking beyond students' academic scores, and using one's experience and background knowledge to find explanations and assess the applicants based on numerous factors. The reviewers have to "read between the lines" to glean more information than what is presented in the applications. When the number of applications increases and there are more contenders for each spot, reviewers have to be more selective. Reviewers are also constantly introspective to ensure they are making reasonable recommendations and when they are doubtful about their recommendations, they put those applications in the queue for second reviews. There are also challenges that are specific to certain kinds of applications, e.g., international applications.
- *Arguing for recommended applicants during committee meetings:* Reviewers are very "invested" in their work and they try to picture themselves in the applicant's shoes while reviewing an application. This investment helps them during the committee meetings when they are faced with the hard task of arguing for their preferred students and convincing the committee why they should be admitted.
- *Balancing various enrollment expectations:* In addition to reviewing individual applications, some of the reviewers also have to view the applications collectively. They attempt to balance various enrollment expectations, such as geographic diversity, skills diversity, majors, special talents, and life experiences, in constructing a well-rounded class.

4.2 Leverage points for applying decision-support tools

The *materialist* perspective centers on how the ways in which information is represented "constrain, enable, limit, and shape" the purposes for which it is used [16]. For example, the currently-used digital applications shape the review process differently from the paper-based applications that were formerly popular. The material consequences extend beyond the differences in how these representations enable reviewing, sharing, storing, and communication; the introduction of digital applications also resulted in a substantial increase in the number of applications received by colleges leading them to be more "selective" and alter their reviewing strategies [24].

We studied the materialities of the digital formats used for applications and reviewers' evaluations and how they shape the current review practices. We discuss the materialities of the specific formats used within the process characterizations presented in Sections 4.3 and 4.4. We found that the

formats used are more *representational* than *interaction-based* and do not adequately support the cognitive processes of the reviewers. In particular, we found that the largely static representations did not sufficiently afford (i) comparisons and other introspective tasks performed by the reviewers, (ii) recording of the rationales for the reviewer recommendations which are subsequently recalled during committee meetings, and (iii) addressing of the subjectivity and potential cognitive biases inherent in the holistic-review process. Towards addressing these limitations, we propose the use of interactive *visual* representations of application and evaluation information in the review process.

Visualization solutions present a promising direction to address the drawbacks identified in the current information formats and review practices given that they have been used for similar purposes in different contexts. However, their efficacy and how they will, in turn, change and shape the review process is not known. Additionally, considering that the admissions process is continually changing, the technology developed to support the process would also involve continuous change, critique, and improvements.

Based on our observations and identified reviewer challenges, we suggest the following leverage points for applying visualization tools under three categories. These suggestions are intended to both assist in decision making during the largely *exploratory* individual application reviews and in turn facilitate presenting applications during the largely *explanatory* committee meetings.

4.2.1 Visual representations of application attributes. The application attributes, including quantitative information, are currently evaluated by reviewers in largely textual formats. Additionally, reviewers consider various statistics to assess an applicant's academic performance and such statistical inferences can be more easily conveyed by visualizations [19]. Visually representing application attributes (that are quantitative, nominal, or ordinal) by choosing suitable visual encodings [31] can facilitate reviewer tasks associated with them.

The attribute types presented are consistent across all the applications with only their values being different for every application. Hence, the same visual templates can be consistently used for all applications.

4.2.2 Integration of Sensemaking and Storytelling tools. We observed that the holistic review process is comparable to *sensemaking* [38, 41]. It too involves careful consideration of information, analyzing and making associations among the various aspects presented, and using the knowledge acquired to make recommendations. Based on the reviewer behaviors observed, we can draw ideas for suitable visual tools from sensemaking domains [6, 41, 51].

During individual application reviews, reviewers explore an application to find prominent aspects that they use as evidence for making their recommendations. While they record their key findings in the decision sheet (used for summarizing applications), the actual reasoning processes in the reviewers' minds consisting of the synthesis of numerous attributes can be quite complex. During the application review itself, keeping track of these reasoning processes can burden the human working memory and impose a cognitive load on the reviewers [41]. It is very likely that these reasoning processes would have long since been forgotten during committee meetings and as a result, the reviewers mostly rely on the decision sheet to recall an application. We can enable reviewers to better articulate their reasoning processes with the help of visual tools enabling knowledge externalization, note-taking, and navigation [6, 41, 42, 51].

These tools can, for example, help reviewers "link" evidence in the application to their opinions, record their traversal through the application and enable more-efficient note-taking by taking quick snapshots of the visual attributes and using digital sticky notes. The rationales thus captured can, for example, inform them to consider alternative claims, help them make a recommendation, and enable them to prune the captured details using narrative and storytelling visualization techniques [25, 26, 40] so as to retain the most important findings for discussion during committee meetings.

4.2.3 Visual strategies to mitigate cognitive biases. Reviewer biases are one of the challenges identified in the process and this is not surprising given that it is human-driven and inherently subjective. As mentioned previously, reviewers, who are subject-matter experts (SMEs), use both their declarative and automated knowledge in reviewing applications. Their automated/procedural knowledge is learned from their experiences. However, reviewer experiences can substantially vary and hence their developed intuitions can be expected to be different as well. Furthermore, the holistic review process is not sufficiently predictable, i.e. the most-appropriate recommendation to make for each application is not obvious and the process also does not offer quick and efficient feedback to the reviewers on their recommendations to help them hone their procedural knowledge [22, 23]. Hence even experienced reviewers can be susceptible to cognitive biases when thinking *intuitively*.

Cognitive biases can range from perceptual biases to reasoning and judgment biases occurring during decision making to those that can be influenced by culture or based on discrimination [49]. We are predominantly interested in identifying and mitigating decision-making biases as part of our study, i.e. the generalizable biases that can be identified through common reasoning heuristics employed in uncertain situations and are not specific to any individual or groups of individuals.

We identify potential reviewer biases in the process by comparing descriptions of known heuristics and cognitive biases in literature [7, 32, 48] with reviewer tasks ascertained through CTA. We then provide strategies to mitigate them where possible. While it is possible to identify potential cognitive biases, determining *important* biases, i.e. ones with the biggest consequences, is non-trivial and it may also not be possible to uncover or to develop strategies to counter some of the biases. In addition to describing the identified potential cognitive biases within the characterizations, a summary of the biases and visualization strategies for their mitigation is also presented in Table 1. While some of the strategies are drawn from bias literature and are not "visualization" strategies per se, they can also be implemented using the visual representations that we propose to use in the review process. The rationales for the possible reviewer biases and visualization approaches for their mitigation are discussed in more detail in our other work [44, 45].

While we propose visualization approaches to address reviewer biases, we are also aware of the challenges they entail and that devising perfect solutions for alleviating the biases is an impossibility. Visualizations are being continually explored in relation to bias mitigation and fostering better understanding compared to textual formats in other contexts. For example, visualizations have been designed to enable users to reason with conditional probabilities associated with medical decision-making [30, 35, 47]. While these examples present isolated scenarios and relatively simple problems where suitable visualizations can be designed and evaluated, holistic reviews are far more complex where identifying potential reviewer biases as well as designing and evaluating suitable visualization solutions can be extremely challenging. It is possible that efforts to reduce certain types of biases in the visualizations can result in making the reviewers susceptible to other and also, indeterminable bias types. As Drucker states, visualizations have come to be used almost unquestioningly as forms of data and knowledge *representations* but their functioning as forms of knowledge *production* or interpretation, which are subjective experiences, is less known [18].

Our proposed idea is to visually represent the applications and embed strategies for mitigating cognitive biases as well as tools enabling efficient note-taking and other decision support seamlessly in the interface used for application review. We integrate within the detailed characterizations presented in the following sections *specific* suggestions and discussion regarding (i) the attributes that can be represented visually and the reviewer tasks they can facilitate, (ii) the types of cognitive biases that can occur during certain reviewer tasks and strategies for mitigating them where possible, and (iii) how sensemaking tools can be applied in the process.

4.3 Characterization of Individual Application Reviews

In this section, we provide details on how reviewers assess applications and their thought processes contributing to their recommendations. These details form the crux of the holistic review process at this university. We also mention the computer tools used for reviewing applications and how applications are succinctly summarized to facilitate reviewers' recollection and recapitulation of them at a later time, i.e. during committee meetings.

4.3.1 Software setup. The university requires applications to be submitted through the online-only Common Application [2] or Coalition Application [5] which are used by a significant number of universities and colleges in the United States. In addition to one of these, the university also requires a university-specific writing supplement, and letters of recommendation (from Counselor and Teacher) to be included with the application.

For review purposes, the university employs document-management software customized to their purpose which gathers and organizes entire submitted applications in one database. It also provides tools to accelerate and ease the decision-making process, such as tools for communication among reviewers, automatically generating codes for certain application attributes, enabling annotation and including a decision sheet with every application to record reviewers' comments and ratings for the respective application. Reviewers access applications prepopulated on the software and it synchronizes all the documents and information entered across the system so that all the information is uniformly visible to all the reviewers. Reviewers use conventional desktop systems for reviewing applications and some of them used multiple screens (2-3) for viewing.

Discussion: The materialities of the digital database enable efficient organization, storage, retrieval, and distribution of the applications. Additionally, they also enable coordination or "multiplicity" [16] for multiple reviews for a single application, and make the reviews transparent. However, they are largely representational rather than interaction-based with *annotation* being the key interaction tool.

4.3.2 Decision sheet. The decision sheet for every application serves to record the key points, both objective and subjective, about the various attributes that the reviewer encounters while reading the application. It has text-fields allocated to specific attributes and text-boxes for the reviewers to enter their viewpoints, summaries, and rationales for their recommendation. Much of the information entered in the decision sheet for attributes including demographic, academic, extracurricular, and personal information is in the form of "codes". An example code is "APAH" for the AP American History (Advanced Placement) course. There can be hundreds of such codes. The decision sheet is essentially the succinct summary of the application's review which not only enables the reviewer to make a recommendation but also helps the reviewer to recall and present an application during the committee meetings.

Discussion: In studying the materialities of the digital database, we observed that the review process is intrinsically *shaped* by the decision sheet. The reviewers appeared to think of reviewing as being synonymous with filling out the decision sheet. They also thought of others' reviews and the committee-meeting discussions in terms of the decision sheet. The codes or abbreviations used enabled compact representation, quick input, "tagging", and recognition of tags for applicants. However, the reviewers are required to be familiar with the various codes to use them efficiently.

We observed that the cognitive processes of reviewers associated with reviewing an application amounted to more than the brief summaries they entered in the decision sheet. This, in turn, can constrain how they recall and discuss the applications during the committee meetings.

By visually representing the application attributes, we can also record their visual summaries in the decision sheet by means of note-taking and navigation tools [6, 41, 51]. This can help reviewers

see their reasoning trail and make better-informed recommendations. The decision sheet can be populated with snapshots of attribute summaries and excerpts from essays with embedded reviewer comments and link these snapshots to their locations in the applications. The numerous codes used in the decision sheet can be replaced by visual icons; for example the non-academic activities can be replaced by visual symbols representing the activities. Additionally, large screen spaces are known to support sensemaking tasks [6, 42]; hence the multiple screens used by reviewers can be leveraged to enable the above functionality.

4.3.3 Overview. Every application is carefully reviewed and many are reviewed multiple times by multiple reviewers. The order in which the application attributes are reviewed differ among the reviewers and they also often go back and forth between various attributes before making a recommendation. Typically, reviewers begin with viewing the demographic information of the applicant followed by the assessment of the applicant's academic performance before reading the letters of recommendation and assessing the non-academic achievements. Reviewers usually read the essays last before considering the applicant's preferred major(s) and summarizing their viewpoints of the application.

4.3.4 1. Demographic Information. The application records the applicant's demographic information.

4.3.5 2. Family Background. Reviewers typically look for information about the applicant's family, i.e. if parents are married, what are their educational backgrounds, alma maters and professions, if the applicant has siblings and if yes, what are their occupations and if any of them has applied or has been admitted to this university.

“what's the household like? parents married, dad lawyer, mom business executive .. three kids, oldest kid goes to [some university] ... household with a lot of opportunities”

Discussion: Reviewers often gauge the socioeconomic status of the applicant from this information and if, say, they think that the applicant is from a privileged background and/or is the only child, they keep in mind that the applicant has been given ample opportunities while assessing his or her application attributes. While the strength of holistic reviews lies in such associations made by reviewers, they can also sometimes lead to cognitive biases. In this example, the bias due to *illusory correlation* associated with the *availability* heuristic [48] can result wherein strongly-associated events are believed to invariably co-occur.

4.3.6 3. Academic Performance. The academic achievements of the applicant directly influence the recommendation made on the application. There can be variation in the grades and scores on standardized tests (SAT/ACT) among applicants but applicants' uniqueness and life experiences can equalize their opportunity for admission.

4.3.7 3.1 High school context and statistics. Several factors are taken into account when assessing an applicant's academic performance. The student's high school provides the main context for interpreting the student's academic performance. Reviewers are generally familiar with the high schools in their assigned geographic area and utilize information regarding the school's profile, diversity, and courses offered in their assessments. Reviewers consider the student's grades and understand what the grades mean compared with the rest of the class. The student's rank in class, if provided by the school, is very helpful to the reviewers. Admissions officers in selective universities are concerned about the growing trend of schools not providing them with the class rank information of students which may make it impossible for them to even calculate an “in-the-neighborhood” class rank estimate. The distribution and mean/median assessment of the SAT

and ACT scores for the entire senior class provided by the school are also considered in assessing and comparing the competitiveness of the entire class from one school to another.

Reviewers also consider the school's statistics from previous years and make some calculations regarding how many students from this school were previously admitted to this university and what is their average GPA, and what other universities or colleges have students from this school been admitted to. They assess where the applicant in question stands with respect to his or her present class as well as the students from the school admitted to the university in the previous years.

"school profile - great. 98% four-year college-going rate. Students accepted into [top universities] ... Good opportunities provided by school"

4.3.8 3.2 Grade-trends. Reviewers also look for trends in grades, i.e. is there an upward or downward trend, or are the scores consistent, and are there any low scores that particularly stand out.

"Grades have all been straight As, good school"
 "whole bunch of As, Bs .. why does she have Bs?!"

4.3.9 3.3 AP courses and "rigor". Reviewers scrutinize the courses taken by the applicant and check the number of Advanced Placement (AP) courses offered by the school and the ones taken by the applicant, assess if the applicant has taken advantage of the courses offered by the school, if the applicant's courses satisfy the university's course-requirements (Math, Science, History, Foreign Language and English), and if the applicant has challenged himself/herself and demonstrates "rigor." Reviewers enter the key findings and their opinions regarding the above factors in the decision sheet.

"... taking a strong curriculum, she seems to be challenging herself ... trend was up and rigor is getting better"
 "Looking at rigor.. 8 AP classes, student has APs in all the 5 required courses"

Discussion: The digital application database does not adequately support the reviewer tasks for evaluating an applicant's academic performance. Many of the tasks, such as ascertaining the merit of an applicant's grades and scores with the help of statistical information from the high school, finding grade trends and "rigor" in the courses taken, are all done *manually* by the reviewers and human error can possibly occur in such manual evaluations.

The variables and statistics considered, e.g., SAT/ACT scores, grades, school's previous years' statistics, can be represented visually by selecting appropriate encodings [31] to enable reviewers to interpret them more easily and facilitate tasks such as comparing scores, finding trends in grades, highlighting particularly-low scores, and visualizing student's rank in class. The required courses can be color-coded enabling reviewers to quickly spot them in the transcripts. Additionally, more efficient note-taking tools can help reviewers attach "evidence" in the form of visual snapshots with their comments and enter them in the decision sheet.

The reviewer tasks associated with the assessment of academic performance are also subject to cognitive biases. We observed that reviewers better remembered students they interacted with during their high-school-visits and those who frequently contacted them via email. Reviewers also tend to recall a lot of information about the school from their high-school-visits during their review tasks (3.1 above). In both these examples, the bias due to the *retrievability of instances* associated with the *availability* heuristic [48] can occur wherein the information recalled can be incomplete or biased. In the latter case, availability bias can be mitigated by presenting all the information needed to assess an attribute concurrently including those easily recalled and not easily recalled by the reviewers [29].

Since most reviewers assessed the academic factors first before considering other attributes, the academic performance of the applicant can act as an *anchor* leading to *anchoring* bias [48] where they have a bearing on the subsequent attribute assessments. For example, if an applicant has excelled in academics, the reviewers may be more optimistic about the applicant's competence in other aspects. To counter *anchoring* bias, the order of the attributes presented can be rearranged so that *conjunctive* attributes, i.e. those that are affected by the anchor, are considered non-sequentially.

4.3.10 4. LoRs and TE. Reviewers read the letters of recommendation (LoRs) and teacher evaluation (TE) to find if any distinctive aspects about the student are mentioned, or if explanations for any low grades are provided, or to see if they confirm the student's talents and capabilities and make a note of the key findings in the decision sheet. Experience makes reviewers more astute and they can quite easily decipher if the LoRs lack genuineness or exaggerate the student's accomplishments or merely restate what is already known about the student.

"lists qualities.. explains why [the applicant] didn't do well in her first year."
 "[Letter says student is] reliable, [has a] sophisticated understanding of materials "
 "Always looking for something to help me fight for this kid. Searching."
 "[Letter says student] persevered through adversity, tested his limits - but needs it to be backed up somewhere else"
 "[student's] father had a heart attack .. now the human side steps in"
 " this kid is a rank 9 [in entire school] and there's no LoR from the guidance counsellor.. why?!"

Discussion: Excerpts from the LoR and essays (discussed in 5. below) usually make for interesting discussion points during the committee meetings. In reading the LoRs as well as the essays, the reviewers may be prone to *confirmation* bias [32] and as a result, may find and favor evidence that matches their judgments regarding the applicant and overlook or disfavor evidence that disconfirms their judgments.

Single-text visualization methods focusing on capturing the meaning, emotion, writing style, and an overall feel for the text [27, 33, 50] can assist reviewers in their perusal of LoRs and Essays. They can not only help the reviewers in identifying the salient points but can also counter confirmation biases.

4.3.11 4. Non-academic activities. Considerable weight is given to the non-academic activities of the applicant. These activities can include notable achievements in community service, heading student organizations, varsity sports, and talents in music and fine arts. These activities are recorded on the decision sheet using codes. Reviewers not only evaluate the time the applicant has invested in pursuing those activities but also assess the quality of work done or skills attained. They also take into account the student's background and the opportunities, or lack thereof, that the student may have been exposed to in determining his or her competence.

"so many non-profit organizations founded..that's a bit contrived"
 "[activities:] runs track.. hurdles co-captain ..what is that?!"
 "has done some service.. but nothing consistent.. did the student do service just to make up for lack of activities?"

4.3.12 5. Essays. The applicant's essays provide reviewers with a window into his/her personal life and allow them to consider the applicant's perspective and individuality. Reviewers build a character profile of the applicant based on the essays, e.g., "vulnerable", "risk-taker", "perfectionist", "uptight". They especially regard the applicant's university-specific writing supplement with interest and see if the missions and spirit of the university resonate with the applicant to deem if the applicant will be a good "fit" to the university. Reviewers try to predict how the applicant

might mingle with his peers, the singular flairs he/she will bring to the campus, and the roles the applicant may take on while at university.

“ [has] a sibling who has [a mental disorder].. has been involved with his brother’s struggle ... so the student has dealt with some adversity. The story is personal, touching”
 “really into music, uses big vocabulary words”
 “she is a good emotional-match to [the university]”
 “uses the extra space on the application to write about himself.. comes out as honorable”
 “... would be a good friend to others in his dorm”
 “risk taker.. doesn’t want to be put in a box”

Discussion: In addition to *confirmation* bias discussed above, the reviewers may be prone to the *insensitivity to predictability* and *illusion of validity* biases associated with the *representativeness* heuristic [48] when assessing an applicant’s fit to the university. The attributes considered may not be predictive of the applicant’s fit but the reviewers may nevertheless consider their assessments valid. The task of determining fit is subjective and it may be useful for the reviewers to collectively decide on the factors to consider and present these factors alongside the essays during reviews. This may both reduce the bias as well as standardize the task.

4.3.13 6. *Major preference(s)*. Reviewers also see if the student’s major preference(s) match the courses taken by the student.

“... applying to [the Business department].. Finance - sole intent ... if truly interested in [this university], applicants will usually list an alternative major”
 “Majority of courses in Social Science.. Is this really a business kid? This is in the back of my mind [Applicant has listed Business as preferred major]”

4.3.14 7. *Optional Resume*. Applicants can include a resume with their application and the reviewers generally expect it to mostly contain the same information as the rest of their application.
 “additional resume submitted - not included in application. Sometimes demonstrates that the student is from a privileged background and knows and has the means to put together a resume”

4.3.15 8. *Reviewer ratings and final recommendation*. Reviewers provide academic and non-academic evaluations for the applicant based on their impressions. They also evaluate on leadership qualities and other special talents of applicants. All their evaluation scores are entered in the decision sheet along with the final summary. Finally, the reviewers recommend to admit, reject, or waitlist the applicant.

“If it’s a maybe, I’ll see the kid again at committee”
 “at the end of the day, there will be more compelling students [recommendation:waitlist]”

4.4 Characterization of committee-meeting-proceedings

Committee meetings take place after the individual application reviews and a portion of the reviewed applications are discussed during these meetings. We observed that these meetings are largely *explanatory* in nature. The reviewers present their applications and explain the rationales for their recommendations to the committee. While others sometimes provide inputs based on quickly browsing through the applications, the recommendations already made on most of the applications don’t change and no additional discussion material is recorded. However, in the case of undecided applications, i.e. ones where the first and second reviewers’ recommendations don’t match, the committee may make recommendations collectively or a senior member may make the final recommendation. In this section, we discuss the typical sequence of events occurring during

the meetings, i.e. how reviewers present their applications, and how the committee discusses these applications.

4.4.1 Software setup. A file containing applicant summaries is displayed on a large shared screen in the meeting room. The file lists applicants ordered by school and by GPA within each school. The rows represent applicants and their application attributes including recommendation made, and codes for major, demographic, academic, personal and extracurricular information are listed as columns. The committee members access the document-management software on their individual laptops and view the decision sheet and application of the applicant being discussed.

Discussion: The displayed file resembles a static *spreadsheet* with information displayed in "grids", which is the most common type of digital artifact used in group activities within organizations [16]. The materialities of the spreadsheet mainly include serving as an "agenda" for the discussion of applications and presenting application and review summaries for each applicant in a row. Reviewers can be said to "own" the rows of applicants whose schools fall within their assigned geographic regions and for which they are the primary reviewers.

The spreadsheet format enables a compact and aligned display of information, especially through the use of codes for the various attributes. However, projecting the rather ornate application information onto a grid format and reducing the entire information for an applicant to a row may limit the ways in which the applications are discussed during the meetings [16].

4.4.2 Overview. There are usually several members and a leader present during the meetings. The members each have a set of applications to present from their assigned geographic area(s) and for which they are the primary reviewers. The applications are presented in the order of their school groups.

Reviewers verbally present an application to the committee with the help of their notes on the decision sheet and any other notes they may have recorded while reviewing the application. The presenters usually begin with a brief summary of the application and academic factors and then quickly arrive at the rationales for their recommendation, i.e. mention some aspect(s) that particularly impressed them and/or mention shortcomings in the application. The presenters lead the discussions on their applications and appear to have an upper hand regarding the recommendation made because of their familiarity with the application.

Discussion: The presenters tell the *stories* of the applicants based on their findings from the individual reviews. The visual strategies proposed to capture their reasoning processes in a more organized and structured fashion can also help them in recalling an application better and to communicate their rationales more clearly to the committee. Narrative and storytelling visualization strategies [25, 26, 40] can be used both to record as well as organize the visual summaries in the decision sheet to create succinct and coherent stories for presentation to the committee. They can also help counter the availability bias that may occur due to *retrievability of instances* [48] by providing a broader context and evidence for their rationales.

4.4.3 1. Brief summary. The presenters set the tone for the applicant right from the start based on their recommendation and this recommendation is also visible to the committee. They typically introduce an applicant by mentioning his or her demographic information and by providing a very brief summary.

4.4.4 2. Applicant's family. The presenters usually mention the applicant's parents' occupations, educational backgrounds, and alma maters and if they are alumni of the same university. They also mention information about the applicant's siblings (if any) - where they are studying and if they applied to and were admitted to this university.

	Potential cognitive biases	Visualization strategies for bias mitigation
4.3 Individual application reviews	4.3.5 Family Background <i>Illusory correlation</i> associated with the availability heuristic [48] occurring when associated events are always thought to co-occur, e.g., wealthy family and ample opportunities	Breaking down applications attribute-wise and enabling the review of attributes independently and in different orders [22]
	4.3.6 Academic Performance 1. <i>Retrievability of instances</i> associated with the <i>availability</i> heuristic [48] which can cause reviewers to better remember the information of certain high schools 2. <i>Anchoring</i> bias occurring within applications where attribute encountered (usually academic) prior to the current one may influence the evaluation of the current one. 3. <i>Confirmation</i> bias occurring when reviewers find and favor evidence that confirms their judgments	1. Presenting all the information needed to assess an attribute concurrently that are both easily recalled and not easily recalled 2. Same strategy listed above for <i>illusory correlation</i> 3. Presenting alternative visual representations of attribute information to enable more introspection
	4.3.10 LoRs and TE <i>Confirmation</i> bias as in Academic Performance	Single-text visualization methods for highlighting salient points [27, 33, 50]
	4.3.12 Essays 1. <i>Confirmation</i> bias as in Academic Performance 2. Biases associated with the <i>representativeness</i> heuristic in assessing an applicant's "fit" to the university which can be subjective and insufficiently predictable	1. Same strategy used for LoRs and TE 2. Deciding on the factors to consider and present them alongside the essays or along with the single-text visualization methods
4.4 Committee meetings	Reviewers present their review summaries and recommendation rationales for applications 1. <i>Narrative fallacy</i> [22] occurring when there is a tendency to present "tidy", coherent stories of applicants 2. <i>Confirmation</i> bias occurring when reviewers present those aspects that confirm their judgments 3. <i>Availability</i> bias occurring when reviewers recall those aspects that are easily retrieved from memory	The visual sensemaking tools described in Section 4.2.2 can enable the capture of more descriptive review summaries and help in more accurate recall and link rationales to evidence in the applications

Table 1. A summary of the identified potential cognitive biases occurring during the steps of individual application reviews and committee meetings and corresponding visualization strategies for their mitigation.

Occasionally, if this information is not mentioned by the presenters, other members ask the presenters about them.

4.4.5 3. *Academic performance.* The presenters then elaborate on the high school context and the academic performance of the applicant. The key findings regarding the academic accomplishments that were observed during the individual review are stated. Examples include strong test scores, AP courses taken, demonstration of "rigor", student's rank in class, unimpressive scores, and trends in grades.

While the presenters are mentioning the above information, other members contribute to the discussion by mentioning some particularly interesting scores of the applicant or that the applicant would struggle if admitted given certain poor grades or they compare the applicant's grades with other students in the school or summarize grade trends. Members also occasionally mention interesting facts about the school, e.g., "students from this school get into Ivy Leagues". They also refer to previous years' statistics to make recommendations, e.g., "what have we done in the last 5 years at this school?"

"15th [rank] in class out of 259.. not the topmost in class"

Overall ideas for visual tools	Observations and findings of the review process they address	Suggestions for possible improvements
Interactive, visual representations of application attributes and the decision sheet	- Attributes are currently presented in textual formats. - Reviewers experience considerable cognitive load and time pressure when reviewing applications.	- Visual encodings can be chosen for the various scores, statistics, and categorical attributes to facilitate reviewer tasks associated with them [19]; appropriate marks and channels can be selected by developing data and task abstractions [31]. - For example, <i>position on a common scale</i> can convey a student's SAT/ACT scores with respect to the range of scores of admitted students, and the required AP-courses can be color-coded to find them easily in the transcripts [31]. - Single-text visualizations [27, 33, 50] can aid reviewers in identifying salient and affective points when reading LoRs and essays. - Snapshots of these visual representations can be included in the decision sheet.
Visualization strategies to mitigate cognitive biases	Cognitive biases can be expected to occur given the subjectivity in the process and the possible development of inconsistent reviewer intuitions as a result of different reviewer experiences and the holistic-review process being insufficiently predictable.	- Possible biases in the process can be identified by comparing reviewer tasks with definitions of known biases in literature [48]. - A summary of the possible reviewer biases occurring during the review process and visualization strategies for their mitigation is presented in Table 1.
Integration of sensemaking and storytelling visualization tools	- The cognitive-intensive review process is comparable to sense-making. Reviewers make numerous associations among applicant attributes and record their key findings to help them make recommendations. - They also use their recorded findings to present applicant <i>stories</i> during committee meetings.	- Efficient note-taking and navigation tools can be used to take quick snapshots of visual attribute summaries, excerpts from LoRs and essays, enable <i>in place</i> digital sticky notes to hold comments, record reviewer's reasoning trail in the decision sheet and link these to "evidence" in the application [6, 41, 51]. - The captured detail in the decision sheet can be shaped using narrative and storytelling visualization strategies [25, 26] to create succinct and coherent stories for presentation to the committee.

Table 2. A summary of our suggested visual decision-support tools linking the overall ideas to the observations and findings of the review process on which they are based, and listing suggestions for possible improvements.

4.4.6 4. Non-academic and personal attributes. In presenting the non-academic attributes of the applicant, the presenters mention aspect(s) that appealed to or impressed them and/or did not impress them.

These aspects include the applicant's non-academic activities, notable events that occurred in the student's personal life (e.g., parents' divorce), commendable personal qualities of the student (e.g., very communicative), something endearing or exciting or creative that the applicant has mentioned, or the singular perspectives and experiences, such as cultural, that the student might bring to campus or the applicant's essays (e.g., applicant has written a poem about the university). This information is also usually already recorded in the decision sheet.

Other members mention additional interesting aspects they find in the application regarding these attributes during this discussion and the committee concurs.

“[student’s] non academic activities are not that impressive.. he is the only child.. nothing to push the him over the edge”

“[student] was deferred before but he retok the SAT and got a [high score]” (Committee thinks it’s very impressive)

“[student’s] father was an alcoholic and he writes about this in his essay” (Committee sympathizes with the applicant)

4.4.7 5. Rationales for final recommendation. The presenters then put their arguments together to summarize the rationales for their recommendations. They sometimes also ask the committee if their recommendation is "OK".

“I think he’s a great fit to [the university]”

“solid student [academically] but nothing stands out”

“the student would have gained admission if their academic scores had been higher ”

4.5 A Note on Class Construction

We briefly touched on this final aspect of admissions decision making while listing the challenges faced by reviewers. We discuss key features of this step based on what we found in literature [1, 28, 36]. Generally speaking, this aspect is separate from the review process and this is where the applications are viewed collectively and final decisions are made.

The senior members in the admissions department are involved in final class construction and they try to shape the class in accordance with the university’s mission and enrollment goals. They try to craft a balanced class that fits the particular institution’s goals, such as being a good representation of the overall population or one that takes advantage of the educational programs offered [1]. This can be a very challenging task during which concerns of over-enrollment can also arise forcing the admissions officers to revise their decisions accordingly [1, 28]. This tells us that there may be more considerations involved in constructing a class in addition to those of the review process.

The details of class construction have not been studied in recent research [28], although this step of the process may also present opportunities for employing visualization tools. For example, Diversity Maps [37] can be used to visualize the multivariate information of groups of applicants to help the admissions officers see the big picture and how well the constructed class fulfills their institution’s enrollment goals.

5 CONCLUSION

Holistic reviews provide an equitable means to make admissions decisions but have the drawbacks of being subjective and different in practice across colleges. We studied the holistic review process at a highly-selective, private university through direct observations and interviews. We not only obtained a very-detailed picture of the nuanced and complex review process but also learned the elusive complexity of the admissions process of which the review process is a part, thereby proving the aptness of "the shape of the river" analogy mentioned in the beginning of this paper.

We have presented detailed characterizations of the holistic review process along with the background information needed to understand the process. The information visualization tools suggested can not only ease the cognitive load experienced by reviewers and reduce the time taken to review applications [19] but can also improve other aspects of the process; for example make aware of or mitigate cognitive biases of reviewers and assist in capturing their rationales for recommendations more completely and coherently. A summary of our suggested visualization decision-support tools is presented in Table 2. While our suggested tools can be useful for other

universities also employing holistic reviews, tool-design for other universities should ideally proceed from similar studies characterizing their review processes.

Our work has implications for how future admissions-related research should be conducted in CSCW and HCI. The current policies and practices of review processes in colleges, in general, have come to be after numerous developments and amendments over the years and have important sociological foundations. Hence, it is necessary to not only consider the admissions officers' requirements but to also reflect upon the sociological implications when making technological improvements.

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