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The Implementation of the Gale-Shapley Algorithm in School Admission Preferences: An Analysis of Matching Efficiency and Allocation Equity

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Abstract

In today's educational landscape, integrating algorithmic approaches into school admission systems is crucial to ensure fairness, transparency, and efficiency. This study investigates the application of the Gale-Shapley algorithm to address the challenges of student-school matching, which often result in mismatches and inequities. This study aims to explain how the Gale-Shapley algorithm can ensure stable student placement, where no pair of students prefers each other over the post-assignment. Employing a mixed-methods approach, we combined a literature review with a simulation-based implementation using Python. A test case involving four students and four schools was used to validate the algorithm's performance. The preferences of both students and schools were modeled, and the Gale-Shapley algorithm was applied to generate stable matchings. Authors analysis focused on evaluating the stability, fairness, and efficiency of the outcomes. The results demonstrate that the algorithm consistently produces optimal and conflict-free placements aligned with participant preferences. These findings highlight the algorithm's potential to enhance the equity and effectiveness of school admission processes, particularly when applied to real-world educational settings. The implications of the discussion show that it supports trust in the admission system, because the stability and transparency of the process increase legitimacy and acceptance by all parties, including students, schools, and educational authorities.

INTRODUCTION

The school admission system, which involves matching students to schools, is a critical component of the educational process. Effective and equitable school admission mechanisms are crucial for creating a fair and functional educational landscape Such systems not only benefit individual schools and students but can also contribute to improved overall academic achievement.

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The matching process is equitable when all available school places are fairly distributed among all applicants. However, practical implementation often reveals. mismatches between student preferences and school capacities, resulting in dissatisfaction and inequities within the admission process (Annisa Darma Yanti et al., 2024; Satrial et al., 2024; Triwiyanto et al., 2024).

Unfair matching outcomes can lead to various welfare consequences and empirical evidence of mismatches in school admissions has been observed in numerous countries, including Mexico in United States Glazerman & in China in South Korea and in Indonesia. The Gale-Shapley algorithm emerges as an effective solution to address these issues, achieving stable and optimal matches between students and schools (Syaripudin et al., 2022). This algorithm considers the preferences of both parties, thereby maximizing student satisfaction and efficiently utilizing school capacities.

Matching theory, which studies how the preferences of different parties can determine mutually acceptable pairings is fundamental to developing effective and fair school admission systems. In this context, student preferences are typically expressed as ranked choices of schools, influenced by factors such as educational quality, location, facilities, and extracurricular offerings. School preferences, by contrast, are shaped by institutional policies and criteria such as academic performance and seat availability. To ensure that the resulting matches reflect the priorities and expectations of both groups, it is crucial to incorporate the preferences of students and schools into the admission mechanism (Ade fithrian et al., 2022; Adji & Budiman, 2025).

The objective of this research is to apply the Gale-Shapley Algorithm to the mechanism of student admissions preferences at schools (Sudira, 2024; Wayan, 2025). Leveraging the strengths of the Gale-Shapley Algorithm, this study aims to develop an efficient and equitable school admission system. Additionally, this research evaluates the effectiveness and fairness of the matching algorithm in the context of school admissions, thereby contributing to the ongoing discourse on optimizing admission processes (Aritonang, 2024).

This study explores the literature on matching theory and the Gale-Shapley Algorithm to gain a comprehensive understanding of the concepts, procedures, and benefits of this algorithm within school admission systems. The researchers will implement the steps of the Gale-Shapley Algorithm in Python, utilizing appropriate data structures to represent students and schools (Arsyad & Sauri, 2024; Faruq et al., 2024; Grisma Yuli Arta, 2024; Natasya Lady Munaroh, 2024). Developed by Gale and Shapley (1962), the stable matching algorithm has been widely adopted to pair two parties based on mutual preferences Its core principle is to produce stable matches that honor the ranked choices of both groups.

The time complexity of the Gale-Shapley algorithm is $O(n^2)$, where n is the number of participants (students or schools). This quadratic time complexity arises because each student can make at most n proposals, and each proposal is processed in constant time. Consequently, the algorithm is efficient and feasible for a large number of participants, ensuring that a stable matching is found within a reasonable amount of time. The algorithm iteratively matches students with schools based on their preferences, updating the matches if a student or school prefers another option (Mulyanto et al., 2021; Sirait et al., 2023; Sulaeman et al., 2022). Following the implementation, the researchers will assess the efficiency of the Gale-Shapley Algorithm for matching using simulated data from students and schools. Additionally, an analysis of fairness will be conducted based on current student preferences and school capacities. Consequently, this study is expected to contribute to the development of a more equitable and efficient school admission system that meets the needs of both schools and students.

METHODS

This study employed a mixed-methods approach, combining a comprehensive literature review with algorithmic analysis to investigate the application of the Gale-Shapley algorithm in a new student admission system for determining student and school preferences. We began with a literature review to understand matching theory and the principles underlying the Gale-Shapley algorithm in student admissions (Akem et al., 2025; Albshkar et al., 2025; Markhmadova et al., 2024; Muthatahirin et al., 2025). This allowed us to contextualize the problem of school admissions and identify existing challenges related to matching efficiency and allocation equity. Following the literature review, we proceeded to the core of our study: developing and implementing the school admission steps using the Gale-Shapley algorithm. For practical analysis and initial validation, we selected a random sample of four students and four schools, comprising two Senior High Schools and two Vocational High Schools, as a test case for the algorithm. This balanced representation reflects the common structure of secondary education systems and allows us to explore the algorithm's behavior across different school types. The preferences of these students and schools were defined, and the algorithm was then applied to match these preferences. Subsequently, the efficiency and fairness of the resulting matching process were rigorously analyzed (Ath-Thukhi et al., 2025; Faddhia et al., 2025; Guspita et al., 2025; Ikhlas et al., 2025; Khairunisa et al., 2025; Mustafa et al., 2025; Rahman et al., 2025).

The core of our analysis builds on the stable marriageproblem, a canonical two-sided matching framework rigorously explored in the literature. This problem is to find a stable matching for elements of two n-element sets based on given matching preferences. We adapted Levitin’s pseudocode implementation of Gale-Shapley in our Python code implementation, as detailed below, to address the specific dynamics of student-school admissions. The algorithm iterates proposals and acceptances until a stable matching is reached, i.e., no student-school pair would prefer one another over their current match, exactly as the original formulation guarantees (Jaafar et al., 2025).

Table 1. Pseudocode of Gale-Shapley Stable Matching Algorithm as

proposed by Levitin

```
Procedure StableMatching (M, W)
   Input:
      M ← set of men (e.g., students)
      W ← set of women (e.g., schools)
      Each m ∈ M has a ranked list of preferred w ∈ W
      Each w ∈ W has a ranked list of preferred m ∈ M
   Initialize all m ∈ M and w ∈ W as free
   while ∃ free man m who still has a woman w to propose to do
      w ← first woman on m's preference list to whom m has not yet
proposed
      if w is free then
         (m, w) ← engaged
      else
         Let m' be the current partner of w
         if w prefers m over m' then
            m' ← free
            (m, w) ← engaged
         else
            (m', w) ← remain engaged
         end if
      end if
   end while
   Output: Stable matching pairs (m, w) for all m ∈ M
End Procedure
```

This pseudocode illustrates the fundamental steps of the Gale-Shapley algorithm. Each participant in the proposing group (students) sequentially proposes to the most preferred partner who has not yet rejected them. The receiving group (schools) either accepts the proposal if they are free or compares the new proposal with their current match, potentially switching to a more preferred student (Sandra et al., 2024; Syafril, et al., 2021). The process continues until no further proposals can be made, and all participants are either matched or have exhausted their preference lists. This guarantees a stable matching outcome, in which no unmatched pair would prefer each other over their current match. During the implementation phase, we conceptualized structured steps for matching students with schools based on their preferences, adhering strictly to the principles of the Gale-Shapley algorithm. These steps involve iterative interactions between students and schools until a stable match is achieved, ensuring that both student and school preferences are considered to achieve matching efficiency and allocation equity. Table 1 outlines these general steps as applied to school admissions.

Table 2. The general steps of the Gale-Shapley Algorithm in school admissions

Steps	Process
Initialization	Each student applies to their most preferred school based on their preferences
Initial Selection	Each school selects students who meet their criteria and includes them in a selected group.
Proposals and Acceptance	Students who have not been accepted by their preferred school submit proposals to the next school on their

	preference list. Schools consider the received proposals and select the best students based on their preferences.
Matching Updates	If a student is rejected by their current school and there is another school the student prefers, the student can submit a new proposal. Schools will consider these proposals and update the match if the new student is preferred.
Iterative Proposals and Acceptance	The process of proposals and acceptance continues until no more students submit new proposals or all students are accepted by their best choice school.

Our implementation of the Gale-Shapley algorithm was developed using Python, leveraging appropriate data structures, such as lists and dictionaries, to represent student and school preferences effectively (Syafril, Asril, et al., 2021). Each school was designed to maintain a list of student preferences and a list of applicants (Baroud et al., 2025; Engkizar, Jaafar, Masuwd, et al., 2025; Htay et al., 2025; Mutiaramses et al., 2025). This programmatic approach allowed us to simulate the iterative matching process and analyze the resulting stable and optimal match for effectiveness and fairness. Based on the analytical results obtained, we subsequently drew several interpretations and provided recommendations for the practical application of the Gale-Shapley algorithm within the context of high school or vocational school admissions (Febriani et al., 2023; Sabrina et al., 2024).

RESULT AND DISCUSSION

Implementation of Gale-Shapley Algorithm: The Interchange Between Prospective Students and School Data

In implementing the Gale-Shapley algorithm, we operationalized both student and school preferences using structured data. Students were assigned ranked choices of schools based on predefined criteria such as educational quality, location, and extracurricular opportunities. Schools, in turn, ranked applicants according to internal policies and capacity constraints. This practical encoding of mutual preferences served as the basis for simulating the matching process, allowing the algorithm to generate stable and mutually acceptable outcomes. As previously discussed, the Gale-Shapley algorithm's structure enables the reconciliation of competing preferences in a manner that promotes both efficiency and fairness.

To simulate the matching process, we encoded student and school preferences in Python using lists and dictionaries to represent ranked choices. Each school will have a list of student preferences and a list of students who have applied. By implementing the steps of the Gale-Shapley Algorithm, a stable and optimal match can be produced, which can then be analyzed for effectiveness and fairness.

To achieve fair and efficient matching between students and schools, the researchers implemented the Gale-Shapley Algorithm in the school admission system using Python. We utilized sample data, as shown in Table 2 (student data sample), which indicates that each student applies to or selects their most preferred school based on their preferences. Table 3 (school data sample) signifies the schools' preferences in selecting students who meet their criteria and includes them in the selected group.

Furthermore, the visual representation of the initial preferences as depicted in figure 1 provides valuable insights into the preference structures of both students and schools. It highlights the complexity and potential conflicts that the Gale-Shapley algorithm must resolve to achieve a stable matching. For instance, multiple students and schools share common top preferences, indicating potential competition for certain matches. Understanding these initial preferences is crucial for analyzing the algorithm's performance and the stability of the final matches.

Table 3. Prospective Students data sample

Student	School			
	Preference 1	**Preference 2**	**Preference 3**	**Preference 4**
Student 1	SHS 81	VHS 49	SHS 20	VHS 15
Student 2	SHS 20	SHS 81	VHS 49	VHS 15
Student 3	VHS 15	SHS 81	SHS 20	VHS 49
Student 4	VHS 20	SHS 49	SHS 81	VHS 15

Table 4. School data sample

School	Capacity	Students			
		Preference 1	**Preference 2**	**Preference 3**	**Preference 4**
SHS 81	2	Student 1	Student 4	Student 2	Student 3
VHS 15	2	Student 3	Student 2	Student 1	Student 4
SHS 20	1	Student 2	Student 1	Student 3	Student 4
VHS 49	2	Student 4	Student 3	Student 1	Student 2

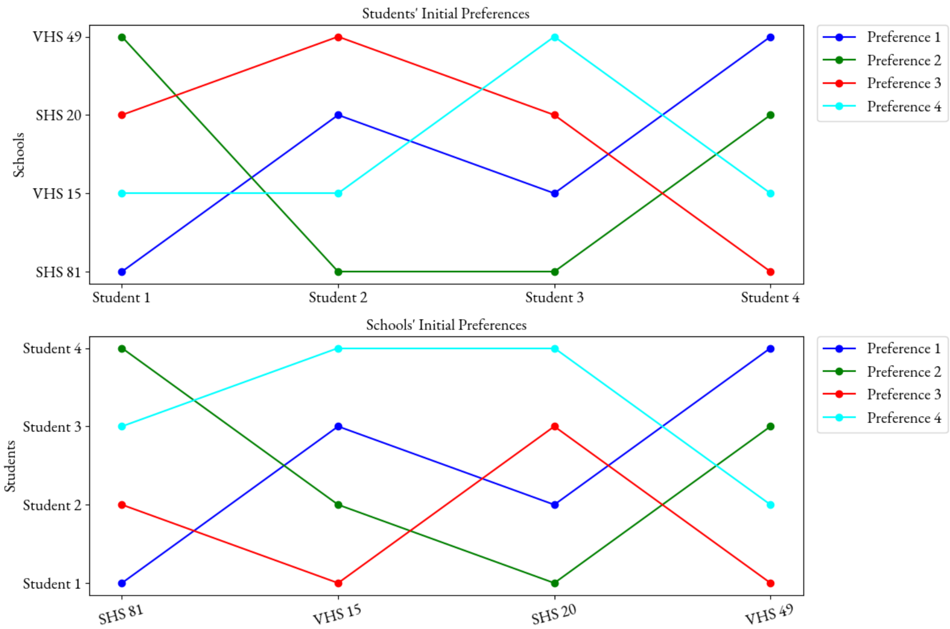

Fig 1. Initial Preferences of Students and Schools

After identifying the sample data for the algorithm to process, the researchers wrote the code to correctly implement the Gale-Shapley algorithm for matching students to schools based on their preferences and the schools' capacities and preferences. We ran the code in verbose mode. The results indicate that student 1 is matched with SHS 81, student 2 is matched with SHS 20, student 3 is matched with VHS 15, and student 4 is matched with VHS 49 after two iterations. After obtaining the results, we visualized the final matches using Python, as shown in Figure 2 below.

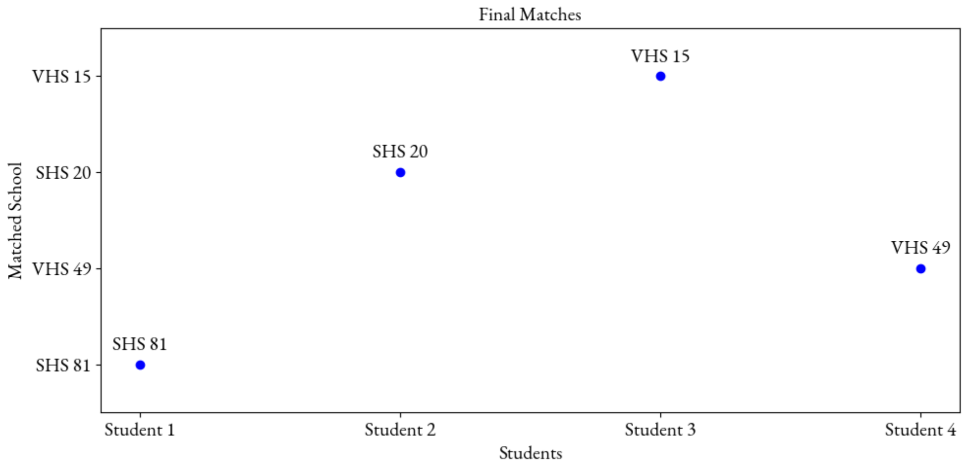

Fig 2. Final matches of the students to their respective schools

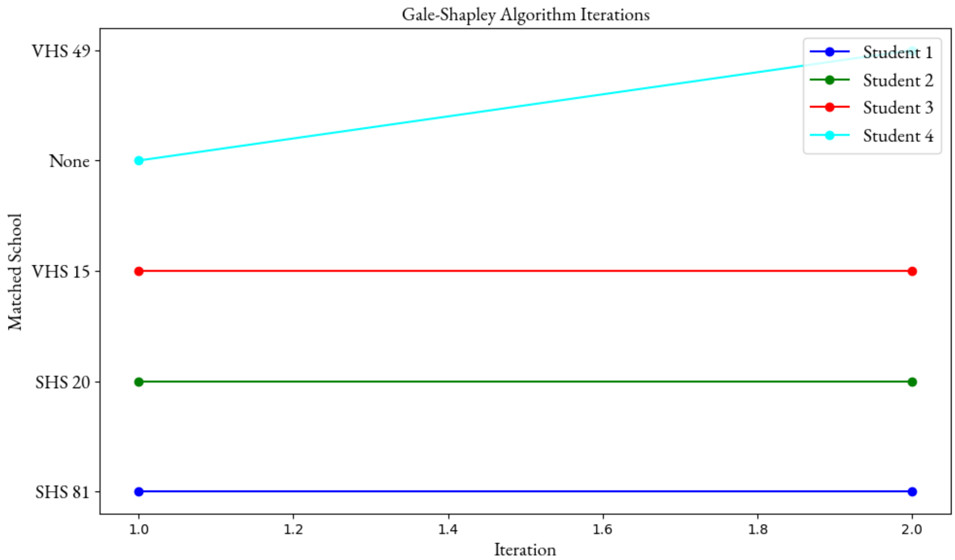

Fig 3. Gale-shapley algorithm iterations

After investigating Figures 1, 2, and 3, it is evident that Student 1's top choice was SHS 81, and was successfully matched with SHS 81, indicating a stable and optimal match. The same condition applies to Students 2 and 3. Although initially preferred SHS 20, Student 4 was matched with VHS 49 due to capacity constraints and the preferences of the schools. SHS 20 preferred Student 2, leading to Student 4 being matched with his next preferred school, VHS 49. This results in a stable match given the constraints.

The final matches produced by the Gale-Shapley algorithm are stable, as no student-school pair would prefer each other over their current matches. Each student was matched with a school according to their preferences, and the algorithm efficiently found a stable matching in a minimal number of iterations. In the stable matching process, a matching is stable if it is not blocked by any individual or any pair of agents. This study confirms the effectiveness of the Gale-Shapley algorithm in solving matching problems in school admission preferences, ensuring optimal and stable outcomes for all students and schools.

The Gale-Shapley Algorithm's Efficiency and Scalability for School Admission Matching Preferences

The researcher also conducted performance testing to assess the scalability and responsiveness of the Gale-Shapley algorithm in student admission scenarios, we conducted performance testing with increasingly larger datasets. Performance testing involves identifying how a system performs in terms of stability and responsiveness under increased usage. This method is particularly useful for observing how the algorithm behaves in terms of iteration count and execution time as the input size increases. We designed five test cases ranging from small to large scale to simulate realistic school admission scenarios. Each scenario involved a different number of schools, and school capacity was proportionally adjusted to maintain balance between supply and demand. The tests were run using Python, and the execution time was measured using built-in timing functions. Table 5 summarizes the number of iterations and elapsed time recorded during each test case.

Table 5. Gale-Shapley Algorithm Performance Testing

Test Case	Number of Students	Number of Schools	School Capacity	Iterations	Elapsed Time (s)
Case 1	10	5	2	6	0.000058
Case 2	100	20	5	3	0.000143
Case 3	500	40	5	2	0.000175
Case 4	1,000	60	10	1	0.000564
Case 5	10,000	100	10	1	0.008543

According to Table 5, the results indicate a clear trend in how the algorithm handles increasing input sizes. In Case 1, the small number of schools and limited capacity resulted in a higher number of iterations, as more proposals and rejections were needed to reach a stable match. In contrast, Case 2 and Case 3 showed improved performance due to increased school availability and capacity, which allowed the algorithm to converge more efficiently. Remarkably, in Cases 4 and 5, where both the number of schools and their capacities were significantly larger, the algorithm achieved stable matches in just one iteration, demonstrating its ability to quickly resolve preferences when the system is well-balanced.

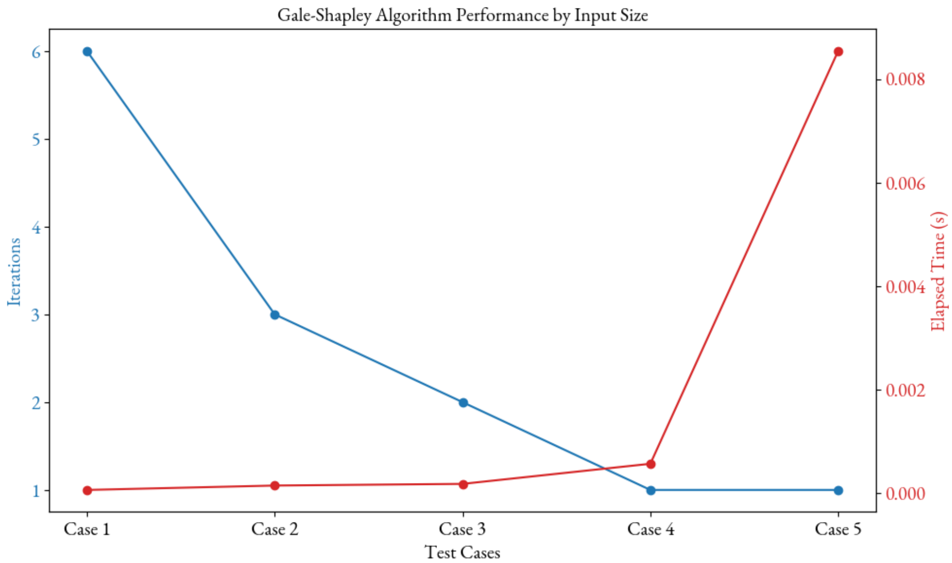

Fig 4. Gale-shapley algorithm performance with five test cases

These findings underscore the scalability of the Gale-Shapley algorithm. Despite significant increases in input size, the elapsed time remains extremely low, and the number of iterations required to reach stability decreases or remains constant. This suggests that the algorithm not only scales efficiently but also maintain high responsiveness, making it well-suited for large-scale matching applications such as real-world school admissions. In conclusion, the performance testing confirms that the Gale-Shapley algorithm is both computationally efficient and highly scalable. It consistently delivers rapid and stable matching results, even when handling thousands of participants, thereby reinforcing its practicality for broader implementation in educational matching systems.

Achieving Stable Student-School Matching: Advantages of the Algorithm and Key Recommendations

The results of the program implementation demonstrate a stable matching between students and schools based on the provided preferences. Each student is successfully placed in their preferred school according to these preferences. This highlights the advantages of the algorithm in achieving stable student-school matching. Table 5 below details these benefits:

Table 5. Benefit of stable Student-School Matching after implementing Gale-shapley algorithm

Benefits	Explanations
Clarity of Preferences	Each student is placed in their preferred school. For example, Student 1 is matched with SHS 81, Student 2 with SHS 20, Student 3 with VHS 15, and Student 4 with VHS 49. Stable matching ensures that students are placed according to their preferences, providing clarity and fairness in the student admission process.
Optimal Acceptance	Stable matching ensures that each school accepts students according to its capacity. No student prefers a school that does not accept them, or a school that prefers other students who are accepted. This optimizes student admissions and ensures that school capacities are neither exceeded nor underutilized.
Conflict Minimization	By using the Gale-Shapley algorithm, which ensures stable matching, conflicts in the student admission process can be minimized, as consistently reported by previous researchers. The algorithm assigns each student to a school based on their stated preferences, thereby reducing the likelihood of dissatisfaction or disputes in the admission outcomes.
Efficiency and Speed	The Gale-Shapley algorithm has reasonable time complexity, allowing it to be used in real-world scenarios with larger numbers of students and schools. In the implementation of this program, stable matching can be achieved with a limited number of iterations, ensuring speed and efficiency in the student admission process.

With stable matching, students and schools can experience significant benefits and certainty in the student admission process. This matching approach reflects principles of fairness, clarity of preferences, and optimization of student placements. Additionally, the Gale-Shapley algorithm used in this program helps avoid dissatisfaction and conflicts that may arise during the admission process. Overall, the implementation of this program provides beneficial and stable matching results for student admissions to schools. Thus, students and schools' benefit from fair, clear, and optimal matching while reducing potential conflicts in the selection process.

Based on the findings of this study, several recommendations are proposed to enhance future research and practical application. First, it is important to conduct trials using larger and more diverse simulation datasets to ensure the algorithm's robustness, effectiveness, and fairness in more complex admission scenarios. Second, future research should expand the model by incorporating additional factors that may influence preferences, such as tuition costs, geographic distance, or special program offerings. Third, the Gale-Shapley algorithm should be piloted in real-world school admission systems to evaluate its practical feasibility and impact at scale. Furthermore, comparative studies with other matching approaches are encouraged to better understand the strengths and limitations of each method. Lastly, researchers may explore the adaptation of the Gale-Shapley algorithm in broader contexts, such as university admissions or other systems requiring preference-based two-sided matching.

CONCLUSION

This study successfully implements the Gale-Shapley algorithm in the school admission context, demonstrating its effectiveness in producing stable and optimal matches by accounting for both student and school preferences. The algorithm enhances transparency, reduces conflicts, and performs efficiently at scale. However, the main analysis was limited to a small simulation which restricts the generalizability of results to real-world admission systems. Although larger datasets were used for performance testing, detailed outcome evaluation was only conducted on the small sample. Additionally, the study assumes complete and unbiased preference data without addressing real-world collection challenges. While fairness is discussed, it is narrowly defined by stability, overlooking broader equity considerations and the unequal benefits of the student-optimal approach. Finally, the lack of a detailed algorithm trace for the sample data may limit clarity for readers unfamiliar with its mechanics. These limitations highlight the need for future studies using larger, real datasets and broader fairness frameworks to fully assess the algorithm's applicability in diverse admission contexts.

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