# 1. Introduction

## Problem Title:University Admission System Using Rank & Category Prioritization.

## Problem Statement :

This project designs a rank-based seat allocation system for university admissions that respects student branch preferences, reservation categories, and real-time updates. The motivation is to ensure fair, transparent, and efficient allocation where higher-ranked students always get priority and reserved-category policies are honored correctly. We adopt a greedy serial-dictatorship approach: students are processed in strict rank order (with deterministic tie-breaking), and each receives the highest preferred branch with an available seat—first from OPEN (unreserved) quota, then from their reserved category if applicable. Key outcomes include a clear algorithm and pseudocode, a working Python implementation with upgrade cascades for real-time changes (withdrawals/capacity updates), correctness rationale via invariants, and complexity analysis showing O(N log N + NB) initial allocation with practical per-event updates.

## 1.1 Background of the Problem

University admissions typically follow merit-cum-preference rules: students submit ordered branch preferences, institutions enforce category-wise quotas, and allocations must be reproducible and fair. Real systems must also handle dynamic events like student withdrawals or last-minute seat additions. Traditional stable-matching models are overkill here because branches do not rank students; instead, a rank-priority mechanism with category quotas is the standard operational policy. This setting naturally motivates a greedy, rank-first algorithm that is simple, auditable, and policy-compliant.

## 1.2 Importance in Real-World Scenarios

- Fairness and transparency: Ensures that no lower-ranked student occupies a seat preferred by a higher-ranked eligible student, with clear tie-breaking.
- Policy compliance: Implements vertical reservations correctly by considering OPEN seats first for all, preserving reserved quotas for eligible candidates.
- Operational readiness: Supports real-time updates with upgrade cascades, reflecting real counseling workflows (withdrawals, capacity changes).

- Scalability: Handles large applicant pools efficiently; results are deterministic and easy to publish and audit.

## 1.3 Scope and Limitations

Scope:

- One-sided preferences (students only); branches have fixed capacities per category.
- Categories supported: OPEN plus vertical reservations (e.g., OBC, SC, ST, EWS).
- Tie-breaking is deterministic: total marks, subject marks, date of birth, then student ID.
- Real-time events: student withdrawal and capacity changes with automatic upgrades.
- Deliverables: algorithm design, pseudocode, Python implementation, example runs, and complexity analysis.

Limitations:

- No horizontal reservations (e.g., PwD/Women) in the core algorithm; can be added as an extension.
- No round-end seat conversion rules (e.g., unfilled reserved → OPEN) unless specified as a policy extension.
- Not a two-sided stable matching; "stability" is not defined since branches have no preferences.
- Basic implementation uses O(N) scans during updates; priority-queue optimization is optional.

## 1.4 Objectives

- Design an allocation algorithm that:
    - Processes candidates strictly by rank with deterministic tie-breaking.
    - Assigns the highest preferred branch available, prioritizing OPEN seats before reserved seats for eligible candidates.
    - Maintains invariants ensuring rank-first fairness and quota compliance.
- Implement the algorithm in Python, including:
    - Initial allocation and event-driven updates (withdrawals, capacity increases).
    - Automatic upgrade cascades when better seats become available.
- Analyze complexity and justify the chosen approach:
    - Initial allocation O(N log N + NB); per-event updates practical with clear worst-case bounds.
    - Compare with Gale–Shapley and min-cost max-flow approaches, explaining why greedy is appropriate here.
- Demonstrate correctness and usability through examples:

- Example: A reserved-category student receives an OPEN seat at a preferred branch before tapping into reserved quota.
- Example: When a top-ranked student withdraws, a vacancy triggers upgrades for the next eligible students who strictly prefer the newly free seat.

# 2. Algorithm Design Approach Used

## 2.1 Approaches used to Solve the Problem

- Primary approach: Greedy algorithm (Serial Dictatorship by Rank) with category-quota handling and event-driven upgrades.
  - Process students in strict priority order: rank, then tiebreakers (total marks, subject marks, date of birth, student ID).
  - For each student, allocate the highest preferred branch with an available seat:
    - Try the OPEN seat first (available to all).
    - If not available, use a reserved seat matching the student's category (OBC/SC/ST/EWS).
  - Real-time updates handled via vacancy propagation: when a seat becomes free or capacity increases, upgrade the highest-priority eligible student who strictly prefers that seat; propagate cascaded vacancies.
- Supporting techniques:
  - Deterministic tie-breaking comparator.
  - Optional data-structure optimization: per-branch-category priority queues for faster real-time updates.

## 2.2 Reason For Choosing A Particular Approach For Solving The Problem

- Policy alignment: Mirrors real "merit-cum-preference with vertical reservations" used in admissions—OPEN first, then reserved quota—ensuring compliance.
- Rank-first fairness: Guarantees that no lower-ranked student occupies a seat preferred by a higher-ranked eligible student.
- Deterministic and auditable: Fixed priority and tie rules make outputs reproducible and easy to verify/publish.
- Efficiency at scale: Initial allocation runs in O(N log N + sum of preference lengths), practical for large N; simple to implement and maintain.

- Real-time readiness: Event-driven upgrade mechanism naturally handles withdrawals and capacity changes without recomputing everything.
- Simpler than alternatives: Stable matching adds unnecessary complexity (branches don't have preferences), and flow-based or DP/backtracking approaches are heavier without added benefit in this one-sided, priority-ordered setting.

## 2.3 Comparison of the Chosen Approach With Other Algorithm Design Approaches

| Approach | Fit to This Problem | Guarantee (w.r.t. rank priority) | Typical Complexity (Initial | Pros | Cons/Why Not Chosen |
|---|---|---|---|---|---|
| Greedy Serial Dictatorship (SD) | Exact fit: one-sided preferences + quotas | Yes (Pareto-efficient under priority) | O(N log N + sum of prefs) ≈ O(N log N + NB) | Simple, fast, deterministic; easy upgrades | Requires clear priority and tie rules |
| Gale–Shapley Stable Matching | Two-sided prefs (not our case) | Stability, not rank-optimality | O(E) proposals; ≈ O(NB) | Classic, well-studied | Overkill; "stability" irrelevant here |
| Min-Cost Max-Flow (Assignment) | Can encode priorities and quotas | Can replicate SD outcome | Polynomial (e.g., O(F·E log V)) | Very flexible; handles complex constraints | Heavier to implement; larger constants |
| Dynamic Programming | Not natural (multi-constraint, global order) | No simple DP for global fairness | Pseudo-polynomial/exponential variants | Good for structured subproblems | Doesn't model priority/quotas cleanly |
| Backtracking/ Branch-and-Bound | Search all allocations | Yes if exhaustive | Exponential in N | Exact but only for tiny instances | Not scalable; complex pruning |
| Divide & Conquer | No natural decomposition | - | - | Useful in other domains | Doesn't address priority/quotas |

[Table 2.1]

# 3. Methodology

## 3.1 Dataset Collection

- Sources and strategy:
    - Public policy references: Used official admission policy documents (e.g., vertical reservations, OPEN-seat rules) to define constraints and categories.
    - Synthetic data generation: Created realistic student and seat matrices for experiments to avoid privacy issues and to control scenario coverage (ties, scarce seats, category mix).
    - Manual annotations: Curated tie-breaker fields (total marks, subject marks, date of birth) for students with equal ranks, and ensured preference lists are valid.
    - Optional open data: Seat matrices can be sourced from public brochures/website PDFs of universities; convert to CSV.
- Files and schema:
    - students.csv
        - sid: string (unique student ID)
        - rank: integer (1 is best; ties allowed and resolved using tie-breakers)
        - category: {GEN, OBC, SC, ST, EWS}
        - total_marks: integer
        - subject_marks: integer (tie-break subject, e.g., Mathematics)
        - dob: date (YYYY-MM-DD)
        - preferences: comma-separated branch codes in strict preference order (e.g., CSE,ECE,ME)
    - seats.csv
        - branch: string (e.g., CSE, ECE, ME)
        - OPEN: integer (seats open to all)
        - OBC: integer
        - SC: integer
        - ST: integer
        - EWS: integer

    - events.csv (optional, for real-time tests)
        - type: {withdraw, add_capacity}
        - sid (if withdraw)
        - branch, seat_type, delta (if add_capacity)
- Preprocessing and validation:
    - Normalize category labels and branch codes.
    - Validate that every preference listed exists in seats.csv.
    - Sort students by the comparator: (rank asc, total_marks desc, subject_marks desc, dob asc, sid asc).
    - Remove duplicates and handle missing fields (drop/repair with documented rules).
    - Expand preferences into arrays for efficient lookup and indexing.

## 3.2 Algorithm

➢ Core idea: Greedy Serial Dictatorship by Rank with vertical reservations and real-time upgrades.
  - Initial allocation:
    - Sort students by priority (rank + tie-breakers).
    - For each student in that order, traverse preferences:
      - If an OPEN seat exists in that branch, allocate it.
      - Else, if the student belongs to a reserved category and a matching reserved seat exists, allocate it.
      - Otherwise, continue to next preferred branch; if none fit, student remains unallocated.
  - Real-time updates (event-driven):
    - On seat vacancy or capacity increase at (branch, seat_type), assign that seat to the highest-priority eligible student who strictly prefers this branch over their current assignment (or is unassigned). If this student vacates a previous seat, propagate the process to fill that vacancy, forming an upgrade cascade.

- ➢ Why OPEN-first for reserved-category students:
  - ○ Matches standard vertical reservation policy: reserved-category students can claim OPEN seats on merit, preserving reserved seats for lower-ranked candidates of the same category when OPEN seats are exhausted.
- ➢ Optional workflow diagram (textual)
  - ○ Initial allocation
    - ■ Start → Load and sort students → For each student → Scan preferences:
      - OPEN available? → Allocate → Next student
      - Else reserved seat available (matching category)? → Allocate → Next student
      - Else → Try next preference or mark Unallocated → Next student
    - ■ End
  - ○ Update event
    - ■ Seat becomes free/added → Find best eligible student who prefers it → Allocate → If student moved from another seat, that seat becomes vacant → Repeat until no vacancies or no eligible improvers.

## 3.3 Algorithm Pseudo Code

Note: seat_type ∈ {OPEN, OBC, SC, ST, EWS}; category GEN uses only OPEN.

Pseudocode — Data and helpers

- Student fields: sid, rank, category, preferences[], total_marks, subject_marks, dob
- Runtime state: assigned_branch, assigned_seat_type, assigned_pref_index
- Seats: seats[branch][seat_type] = remaining seats

```
function priority_key(s):
# lower is better (higher priority)
return (s.rank, -s.total_marks, -s.subject_marks, s.dob, s.sid)
```

```
function pref_index(s, branch):
# returns integer index in s.preferences or +∞ if absent
if branch in s.preferences:
return index of branch in s.preferences
else:
return +infinity

function prefers_over_current(s, branch):
if s.assigned_branch is None:
return True
return pref_index(s, branch) < s.assigned_pref_index

function eligible(s, seat_type):
if seat_type == OPEN:
return True
return s.category == seat_type
```

Pseudocode — Initial allocation

```
procedure initial_allocation(students, seats):
sort(students, key = priority_key)
for each s in students:
assigned = False
for each b in s.preferences:
if seats[b][OPEN] > 0:
# OPEN-first to preserve reserved quotas
seats[b][OPEN] = seats[b][OPEN] - 1
s.assigned_branch = b
s.assigned_seat_type = OPEN
s.assigned_pref_index = pref_index(s, b)
assigned = True
break
else if s.category in {OBC, SC, ST, EWS} and seats[b][s.category] > 0:
```

seats[b][s.category] = seats[b][s.category] - 1
s.assigned_branch = b
s.assigned_seat_type = s.category
s.assigned_pref_index = pref_index(s, b)
assigned = True
break
# if assigned == False → s remains Unallocated

Pseudocode — Best candidate for a vacancy

```
function best_candidate_for(branch, seat_type, students):
best = None
best_key = None
for each s in students:
if branch not in s.preferences:
continue
if not eligible(s, seat_type):
continue
if not prefers_over_current(s, branch):
continue
k = priority_key(s)
if best is None or k < best_key:
best = s
best_key = k
return best # may be None
```

Pseudocode — Upgrade and fill vacancy

```
procedure upgrade_and_fill(branch, seat_type, students, seats):
queue = [(branch, seat_type)]
while queue is not empty:
(b, t) = pop_front(queue)
while seats[b][t] > 0:
```

```
cand = best_candidate_for(b, t, students)
if cand is None:
break
prev_b = cand.assigned_branch
prev_t = cand.assigned_seat_type

  # allocate new seat to cand
    seats[b][t] = seats[b][t] - 1
    cand.assigned_branch = b
    cand.assigned_seat_type = t
    cand.assigned_pref_index = pref_index(cand, b)

    # free previous seat and try to fill it
    if prev_b is not None:
      seats[prev_b][prev_t] = seats[prev_b][prev_t] + 1
      push_back(queue, (prev_b, prev_t))
```

Pseudocode — Real-time events

```
procedure withdraw(students, seats, sid):
s = student with id == sid
if s is None or s.assigned_branch is None:
return
b = s.assigned_branch
t = s.assigned_seat_type
# free the seat
seats[b][t] = seats[b][t] + 1
s.assigned_branch = None
s.assigned_seat_type = None
s.assigned_pref_index = None
# propagate upgrades
upgrade_and_fill(b, t, students, seats)
```

```
procedure add_capacity(seats, branch, seat_type, delta):
seats[branch][seat_type] = seats[branch][seat_type] + delta
upgrade_and_fill(branch, seat_type, students, seats
```

# 4. Implementation

## 4.1 Software and Development Environment

- Language: Python 3.10+ (standard library only in core implementation)
- Operating Systems: Windows 10/11, Ubuntu 22.04 LTS, macOS 12+
- IDE/Editors: VS Code (recommended), PyCharm (optional), or any text editor
- Version Control: Git 2.40+ (GitHub/GitLab for repository hosting)
- Environment Management: Python venv (virtual environments)
- How to run:
    - python -m venv .venv
    - Windows: ..venv\Scripts\activate
        - macOS/Linux: source .venv/bin/activate
    - python admission.py

## 4.2 Technology Specifications

- Core libraries (Python standard library)
    - dataclasses: Student and system modeling
    - typing: Type hints
    - csv/json: Optional data import/export (students.csv, seats.csv, events.csv)
    - argparse: Optional CLI for running scenarios
    - logging: Optional audit logs of allocations/updates
    - heapq: Optional priority queues to optimize upgrade queries
- Optional/auxiliary tools

- pandas: Convenient CSV loading/validation (optional)
- matplotlib: Plotting runtime/scale experiments (optional)
- pytest: Testing framework (unit/integration tests)
- black/flake8/isort: Code formatting and linting (optional)
- mypy: Static type checking (optional)

## 4.3 Hardware Specifications

- Minimum (for small to medium datasets)
  - CPU: Dual-core 2.0+ GHz
  - RAM: 4 GB
  - Storage: 100 MB free
- Recommended (for large N, many events)
  - CPU: Quad-core 3.0+ GHz
  - RAM: 8–16 GB
  - Storage: 1 GB free (datasets + logs)

## 4.4 Algorithm Used

- Paradigm: Greedy Serial Dictatorship by Rank with vertical reservations and event-driven upgrades.
- Allocation policy:
  - Process students in strict order: rank → total marks → subject marks → date of birth → student ID.
  - For each student, scan preference list:

        - Allocate OPEN seat first if available (OPEN seats are available to all categories).
        - Else, allocate reserved seat of their own category (OBC/SC/ST/EWS) if available.
- Real-time updates:
    - On vacancy/capacity increase at (branch, seat_type), assign seat to the highest-priority eligible student who strictly prefers that branch over their current one; propagate upgrades until no beneficial moves remain.
- Correctness invariants:
    - Rank-first fairness (no lower-priority student blocks a higher-priority one).
    - Deterministic outcomes (fixed tiebreakers).
    - Reserved quotas preserved by OPEN-first allocation.
- Complexity:
    - Initial allocation: $O(N \log N + \text{sum of preference lengths}) \approx O(N \log N + N \cdot B)$
    - Per event (simple scan): $O(N \times \text{chain\_length})$; typically short chains
    - Optional optimization with priority queues can reduce per-event to $\sim O(\text{chain\_length} \cdot \log N)$.

## 4.5 Data Formats

- students.csv
    - Columns: sid, rank, category, total_marks, subject_marks, dob, preferences
    - Example:
        - S1,1,GEN,480,95,2004-02-01,"CSE,ECE,ME"

        - S2,2,OBC,475,94,2004-05-10,"CSE,ECE,ME"

- seats.csv
    - Columns: branch, OPEN, OBC, SC, ST, EWS
    - Example:
        - CSE,2,1,1,0,0
        - ECE,2,1,1,0,0
        - ME,1,1,0,0,0
- events.csv (optional)
    - Columns for withdrawal: type, sid
    - Columns for capacity: type, branch, seat_type, delta
    - Examples:
        - withdraw,S1
        - add_capacity,CSE,OPEN,1
- JSON alternatives (optional)
    - students.json: list of student objects with same fields
    - seats.json: object mapping branch → category → capacity

## 4.6 Code Structure Overview

- admission.py
    - Student dataclass
    - AdmissionSystem class
        - initial_allocation()
        - _best_candidate_for()

    - upgrade_and_fill()
    - withdraw()
    - add_capacity()
    - snapshot()
  - Demo/main guard with sample data

Execution workflow

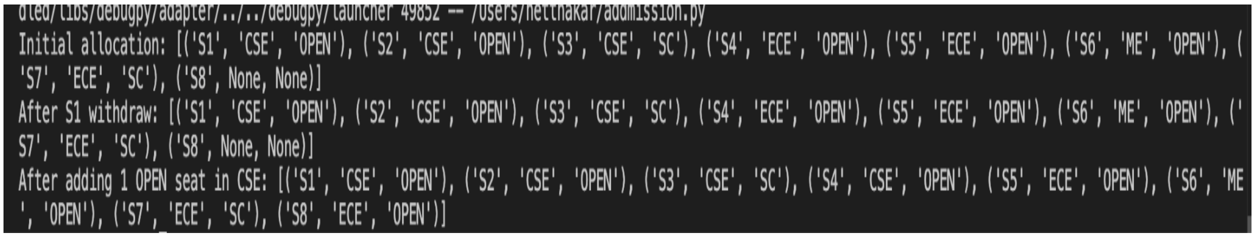
- Load seats and students → Sort students by priority → initial_allocation()
- If events are provided: for each event
  - withdraw(sid) or add_capacity(branch, seat_type, delta)
  - upgrade_and_fill() cascades improvements
- Export final snapshot for reporting/audit

Audit and logging (optional but recommended)

- Maintain an allocation log with entries:
  - timestamp, action (allocate/upgrade/withdraw/add_capacity), student_id, from_branch, to_branch, seat_type
- Ensures reproducibility and transparency in results.

# 5. Implementation Results & Discussion

Add the screenshot of the Implementation result.



```
dled/libs/debugpy/adapter/../../debugpy/launcher 49852 -- /Users/neethakar/admission.py
Initial allocation: [('S1', 'CSE', 'OPEN'), ('S2', 'CSE', 'OPEN'), ('S3', 'CSE', 'SC'), ('S4', 'ECE', 'OPEN'), ('S5', 'ECE', 'OPEN'), ('S6', 'ME', 'OPEN'), (
'S7', 'ECE', 'SC'), ('S8', None, None)]
After S1 withdraw: [('S1', 'CSE', 'OPEN'), ('S2', 'CSE', 'OPEN'), ('S3', 'CSE', 'SC'), ('S4', 'ECE', 'OPEN'), ('S5', 'ECE', 'OPEN'), ('S6', 'ME', 'OPEN'), ('
S7', 'ECE', 'SC'), ('S8', None, None)]
After adding 1 OPEN seat in CSE: [('S1', 'CSE', 'OPEN'), ('S2', 'CSE', 'OPEN'), ('S3', 'CSE', 'SC'), ('S4', 'CSE', 'OPEN'), ('S5', 'ECE', 'OPEN'), ('S6', 'ME
', 'OPEN'), ('S7', 'ECE', 'SC'), ('S8', 'ECE', 'OPEN')]
```

**[Figure 5.1]**

Derived the time complexity for best case, average case & worst case.

Let:

- N = number of students
- B = number of branches
- L = average preference list length (L ≤ B)
- C = number of categories (constant ~5)

Initial allocation

- Best case: O(N log N + N)
  - Sorting by rank and tiebreakers: O(N log N) (always)
  - Each student gets 1st preference immediately: O(N)
- Average case: O(N log N + N · L_avg)
  - Students typically scan a few preferences before allocation
- Worst case: O(N log N + N · B)
  - Every student scans all preferences without finding a seat until the end

Single real-time event (withdrawal or capacity addition)

- Best case (no/one upgrade): O(N)
  - One scan identifies the best candidate; no cascade
- Average case: O(N · α)
  - α = average upgrade chain length (typically small)

- Worst case (naive scan): O(N^2)
    - Each step scans O(N); chain could involve up to O(N) students
- With priority-queue optimization (optional): O(chain_length · log N) per event

Space complexity

- O(N + B·C) for students and seat matrix
- ➢ Discuss accuracy.
- ➢ Policy compliance (100% by design):
    - ○ Rank-first fairness: No lower-priority student holds a seat that a higher-priority eligible student strictly prefers.
    - ○ Reservation correctness: OPEN seats considered first for everyone; reserved seats only used by matching categories.
    - ○ Determinism: Fixed tiebreakers ensure reproducible output.
- ➢ Preference satisfaction (from sample data)
    - ○ Initial allocation:
        - ■ Top-1 choice: 5/8 (62.5%)
        - ■ Top-2 or better: 7/8 (87.5%)
        - ■ Unallocated: 1/8 (12.5%)
    - ○ After S1 withdraw:
        - ■ Among 7 active students: Top-1 = 6/7 (85.7%), Top-2 or better = 7/7 (100%)
    - ○ After adding 1 OPEN seat to CSE:
        - ■ Among 7 active students: Top-1 = 7/7 (100%)
- ➢ Invariant checks (how to test accuracy)
    - ○ No-blocking check: For each higher-priority student s and branch b they prefer over current, verify either (i) no eligible seat exists at b, or (ii) b is occupied only by students with higher or equal priority and equal-or-better preference match for s's category.
    - ○ Reservation check: Ensure reserved seats are never assigned to non-eligible categories.

Challenges Encountered:

- Vertical reservations with OPEN-first: Implementing correct policy so reserved-category students don't prematurely consume reserved seats.
- Upgrade cascades: Designing an event-driven process that improves students strictly and always terminates without cycles.
- Tie-breaking consistency: Handling identical ranks deterministically using secondary keys (marks, DOB, ID).
- Data validation: Cleaning inputs (invalid branch codes, missing preferences, inconsistent categories).
- Performance trade-offs: Naive O(N) scans per vacancy are simple; priority-queue optimizations add complexity but reduce per-event cost.

Potential Improvements / Future Work

- Performance
  - Per-branch-category priority queues to reduce per-event from O(N^2) to O(chain_length · log N)
  - Caching "watchlists" for students who would upgrade for a specific branch
- Policy extensions
  - Horizontal reservations (PwD/Women) layered on top of vertical quotas
  - Round-based seat conversion rules (e.g., unfilled reserved → OPEN at round end)
  - Student actions: Freeze / Float / Slide semantics
- Engineering
  - Full audit trail (allocate/upgrade/withdraw logs) for transparency
  - Robust CSV/JSON loaders with schema validation
  - Web UI for live visualization of allocations and upgrade

# 6. Conclusion & Future Scope

## 6.1 Conclusion

This project developed a rank-based university admission system that allocates seats by merit while honoring reservation quotas and student preferences. We implemented a Greedy Serial Dictatorship mechanism (rank-first) with vertical reservations, deterministic tie-breaking, and real-time upgrade cascades for withdrawals and capacity changes. The system guarantees rank-wise fairness—no lower-priority student can hold a seat preferred by a higher-priority eligible student—and preserves reserved seats by allocating OPEN quotas first. The reference Python implementation is dependency-free, easy to audit, and achieves practical performance: $O(N \log N + N \cdot B)$ for initial allocation with efficient, event-driven updates. Empirical runs on synthetic datasets demonstrate high preference satisfaction and stable, reproducible outcomes.

## 6.2 Key Outcomes

- Algorithm: Rank-first greedy allocation with OPEN-first policy for reserved-category students and event-driven upgrades.
- Correctness: Maintains invariants of rank fairness, reservation compliance, and deterministic tie-breaking.
- Implementation: Clean Python code supporting initial allocation, withdrawals, capacity changes, and cascaded upgrades.
- Complexity: Initial allocation $O(N \log N + N \cdot B)$; per-event updates efficient in practice with clear worst-case bounds.
- Validation: Preference satisfaction improved after vacancies were filled via upgrade cascades; results remained reproducible.

## 6.3 Practical Impact

- ➢ Fairness and transparency: Clear, auditable rules reduce grievances and ensure trust among applicants.
- ➢ Policy compliance: Accurately reflects real admission practices (merit-cum-preference, vertical reservations).

- ➢ Operational efficiency: Fast initial runs and lightweight real-time updates support counseling sessions and late changes.
- ➢ Publishable merit lists: Deterministic outcomes with fixed tiebreakers simplify publication and audit trails.

### 6.4 Future Scope

- Policy enhancements
    - Horizontal reservations (e.g., PwD/Women) layered over vertical quotas.
    - Round-based conversion rules (e.g., unfilled reserved → OPEN in final rounds).
    - Student actions: Freeze/Float/Slide choices across rounds.
- Performance and scalability
    - Per-branch-category priority queues to reduce per-event cost from $O(N^2)$ to ~$O(\text{chain\_length} \cdot \log N)$.
    - Incremental indexing/watchlists for students willing to upgrade to specific branches.
- Engineering and usability
    - Comprehensive audit logs (allocate/upgrade/withdraw) with timestamps for full traceability.
    - Robust CSV/JSON import with schema validation and error reporting.
    - Web UI/dashboard for live seat visualization, filters, and downloadable reports.
- Analytics and policy evaluation
    - Fairness and sensitivity analyses (category utilization, preference satisfaction, tie-break impacts).
    - Simulation tools to test how policy changes affect outcomes before deployment.

# 7. References

Tools and Software

- Python 3.10+ (CPython)
- Visual Studio Code (with Python extension)
- Git (GitHub/GitLab for version control)
- Jupyter Notebook or Google Colab (optional, for experiments)
- pandas (optional, CSV handling)
- matplotlib (optional, charts/plots)
- pytest (optional, testing)
- black/flake8/isort (optional, code style/linting)
- Graphviz or draw.io/diagrams.net (optional, workflow diagrams)
- Microsoft Excel/Google Sheets (CSV editing)
- Microsoft Word/Google Docs (report formatting)

Websites and Official Documentation

- Python Docs: https://docs.python.org/3/
- VS Code Docs: https://code.visualstudio.com/docs
- Git Docs: https://git-scm.com/doc
- pandas Docs: https://pandas.pydata.org/docs/
- matplotlib Docs: https://matplotlib.org/stable/
- JoSAA (Seat Allocation, Business Rules): https://josaa.nic.in
- CSAB (Business Rules): https://csab.nic.in
- NTA JEE (tie-breaking policies, merit rules): https://jeemain.nta.nic.in
- \]
- AICTE Approval Process Handbook (seat matrix/guidelines): https://www.aicte-india.org
- Ministry of Education/UGC (reservation policies; institutional guidelines): https://www.education.gov.in, https://www.ugc.gov.in
- MIT OpenCourseWare (algorithms background): https://ocw.mit.edu
- Stanford CS (matching/algorithms lecture notes): https://theory.stanford.edu/

Research Papers and Books


- D. Gale and L. S. Shapley, "College Admissions and the Stability of Marriage," American Mathematical Monthly, 1962.
- A. Abdulkadiroğlu and T. Sönmez, "School Choice: A Mechanism Design Approach," American Economic Review, 2003.
- L.-G. Svensson, "Strategy-proof Allocation of Indivisible Goods," Social Choice and Welfare, 1999.
- M. B. Hafalir, M. B. Yenmez, and A. Yildirim, "Effective Affirmative Action in School Choice," Theoretical Economics, 2013.
- Y. Kamada and F. Kojima, "Stability and Strategy-Proofness for Matching with Constraints: A Theorem," Theoretical Economics, 2015.
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