Our Approach: Policy, Algorithm, Analysis

<u>Micah Shafer will be uploading the code</u>

Part 1 - Policy

The room assignment method adheres to well-established limitations and preferences to ensure fairness and practicality. Students who require accessible accommodation are assigned entirely to accessible rooms, whereas undergraduate and graduate students are assigned to their respective halls. A structured system is used to incorporate preferences. Each student specifies a three-item amenity vector indicating proximity to supermarkets, downtown locations, and restaurants, a preferred price range (600-1000, 1000-1500, or 1500-2000), and roommate preferences that include compatibility factors such as gender or sexual orientation, as well as schedule alignment (early, late, or flexible). To manage limited resources equitably, priority tiers are based on academic progress. Students with 90-120 credits are given first preference, followed by those with 60-90, 30-60, and less than 30 credits. This tiered priority sequence guarantees that older students are housed first, while also incorporating accessibility, affordability, and preference satisfaction into the matching algorithm to provide a fair and balanced housing distribution.

Part 2 - Algorithm Explanation and Justification

The dorm assignment system utilizes a two-stage algorithmic framework to balance fairness, efficiency, and student satisfaction. In the initial phase, a Maximum-Weight Matching algorithm is employed to form ideal roommate pairs, while in the next step, a Constrained Deferred Acceptance algorithm is utilized for assigning rooms to students and these pairs. These two methods work together to guarantee that assignments adhere to strict system constraints, like accessibility, academic level, affordability, and room capacity, while also optimizing for personal preferences and overall housing satisfaction.

In Stage 1, the pairing of roommates is approached as a graph optimization problem. Each student is depicted as a node, with potential pairings represented by weighted edges. The algorithm assesses the weight of each edge according to various compatibility factors, such as gender/orientation compatibility, accessibility needs, schedule type (early bird vs night owl), and amenity alignment. The objective of the maximum-weight matching is to choose pairings that optimize total compatibility while guaranteeing that each student is matched only once. Compared to random or serial assignment methods, this step greatly enhances the quality of roommate matches.

During Stage 2, individuals (both singles and pairs) engage in a Constrained Deferred Acceptance process. Each applicant (individual or couple) proposes to rooms for which they qualify, ordered based on a composite preference score that considers three primary factors: amenity matches, price-band fit, and pair-fit suitability. Each room assesses applicants using a lexicographic priority rule that first takes into account the student tier (determined by earned credits), then employs a random lottery for tie-breaking, and finally considers the preference score. The DA mechanism proceeds iteratively until no more proposals or reassignments happen, guaranteeing a stable outcome in which no student-room pair would prefer each other over their current assignment. At this stage, fairness and efficiency are combined, ensuring that constraints. like accessibility (students requiring accessible rooms are assigned only to accessible buildings) and level split (UG vs GR halls), are carefully upheld.

Part 3 - Analysis

```
The total number of students whose private bathroom desire was met: 4090
The percentage of students whose private bathroom desire was met: 76.73545966228893
Broken down by student level:
    Postdoctoral: 57 : 95.0%
    Doctorate: 173 : %74.56896551724138
    Masters: 208 : %71.23287671232876
    Senior: 388 : %84.1648590021692
    Junior: 777 : %80.9375
    Sophomore: 1064 : %76.05432451751251
    Freshman: 1423 : %73.88369678089303

The total number of students whose room price is in their preferred price range: 4166
The percentage of students whose room price is in their preferred price range: 78.16135084427768
Broken down by student level:
    Postdoctoral: 60 : 100.0%
    Doctorate: 186 : %80.17241379310344
    Masters: 222 : %76.02739726027397
    Senior: 397 : %86.11713665943601
    Junior: 778 : %81.04166666666667
    Sophomore: 1085 : %77.55539671193709
    Freshman: 1438 : %74.66251298027

The average student-room score (see get_student_room_score() method for details): 12.327868852459016
Broken down by student level:
    Postdoctoral: 14.266666666666667
    Doctorate: 10.974137931034482
    Masters: 10.537671232876713
    Senior: 11.648590021691973
    Junior: 11.108333333333333
    Sophomore: 10.504646175839886
    Freshman: 9.96417445482866

The total number of students who are assigned to a room within a preferred hall: 2790
The percentage of students in a preferred hall: 52.34521575984991
Broken down by student level:
    Postdoctoral: 55 : 91.66666666666666%
    Doctorate: 157 : %67.67241379310344
    Masters: 194 : %66.43835616438356
    Senior: 256 : %55.53145336225597
    Junior: 514 : %53.541666666666664
    Sophomore: 711 : %50.822015725518234
    Freshman: 903 : %46.88473520249221

The total number of students who are assigned to a room that is their preferred residence type: 1961
The percentage of students with preferred residence type: 36.791744840525325
Broken down by student level:
    Postdoctoral: 55 : 91.66666666666666%
    Doctorate: 157 : %67.67241379310344
    Masters: 194 : %66.43835616438356
    Senior: 163 : %35.35791757049891
    Junior: 321 : %33.4375
    Sophomore: 465 : %33.23802716225875
    Freshman: 606 : %31.464174454828658

The total number of students whose laundry availibility was met: 4243
The percentage of students whose laundry availibility was met: 79.60600375234522
Broken down by student level:
    Postdoctoral: 59 : 98.33333333333333%
    Doctorate: 179 : %77.15517241379311
    Masters: 205 : %70.2054794520548
    Senior: 415 : %90.02169197396964
    Junior: 809 : %84.27083333333333
    Sophomore: 1107 : %79.12794853466762
    Freshman: 1469 : %76.27206645898235
```

DATASET A ABOVE

```
The total number of students who are assigned to a room within a preferred hall: 1947
The percentage of students in a preferred hall: 36.529080675422136
Broken down by student level:
    Postdoctoral: 49 : 71.01449275362319%
    Doctorate: 140 : %58.333333333333336
    Masters: 148 : %53.81818181818182
    Senior: 166 : %34.08624229979466
    Junior: 373 : %37.37474949899799
    Sophomore: 441 : %32.213294375456535
    Freshman: 630 : %33.298097251585624

The total number of students who are assigned to a room that is their preferred residence type: 1662
The percentage of students with preferred residence type: 31.18198874296435
Broken down by student level:
    Postdoctoral: 49 : 71.01449275362319%
    Doctorate: 140 : %58.333333333333336
    Masters: 148 : %53.81818181818182
    Senior: 145 : %29.774127310061605
    Junior: 290 : %29.058116232464933
    Sophomore: 387 : %28.268809349890432
    Freshman: 503 : %26.585623678646936

The total number of students whose laundry availibility was met: 3666
The percentage of students whose laundry availibility was met: 68.78048780487805
Broken down by student level:
    Postdoctoral: 64 : 92.7536231884058%
    Doctorate: 188 : %78.33333333333333
    Masters: 202 : %73.45454545454545
    Senior: 348 : %71.45790554414785
    Junior: 742 : %74.34869739478958
    Sophomore: 902 : %65.88750913075238
    Freshman: 1220 : %64.48202959830867
```

```
The average student-room score (see get_student_room_score() method for details): 11.300228021281987
Broken down by student level:
    Postdoctoral: 12.420289855072463
    Doctorate: 10.2125
    Masters: 9.741818181818182
    Senior: 8.562628336755647
    Junior: 8.914829659318638
    Sophomore: 7.87436084733382
    Freshman: 7.805496828752642
```

```
The total number of students whose private bathroom desire was met: 3449
The percentage of students whose private bathroom desire was met: 64.70919324577861
Broken down by student level:
    Postdoctoral: 64 : 92.7536231884058%
    Doctorate: 183 : %76.25
    Masters: 204 : %74.18181818181819
    Senior: 336 : %68.99383983572895
    Junior: 676 : %67.73547094188376
    Sophomore: 848 : %61.943024105186275
    Freshman: 1138 : %60.14799154334038

The total number of students whose room price is in their preferred price range: 3512
The percentage of students whose room price is in their preferred price range: 65.89118198874296
Broken down by student level:
    Postdoctoral: 67 : 97.10144927536231%
    Doctorate: 192 : %80.0
    Masters: 217 : %78.9090909090909
    Senior: 340 : %69.81519507186859
    Junior: 697 : %69.83967935871743
    Sophomore: 850 : %62.089116143170195
    Freshman: 1149 : %60.729386892177594

The total number of students who have at least 3 amenities: 3594
The percentage of students who have at least 3 amenities: 67.4296435272045
Broken down by student level:
    Postdoctoral: 18 : 26.08695652173913%
    Doctorate: 52 : %21.666666666666668
    Masters: 69 : %25.09090909090909
    Senior: 380 : %78.02874743326488
    Junior: 798 : %79.95991983967936
    Sophomore: 978 : %71.4390065741417
    Freshman: 1299 : %68.65750528541226
```

DATASET C ABOVE

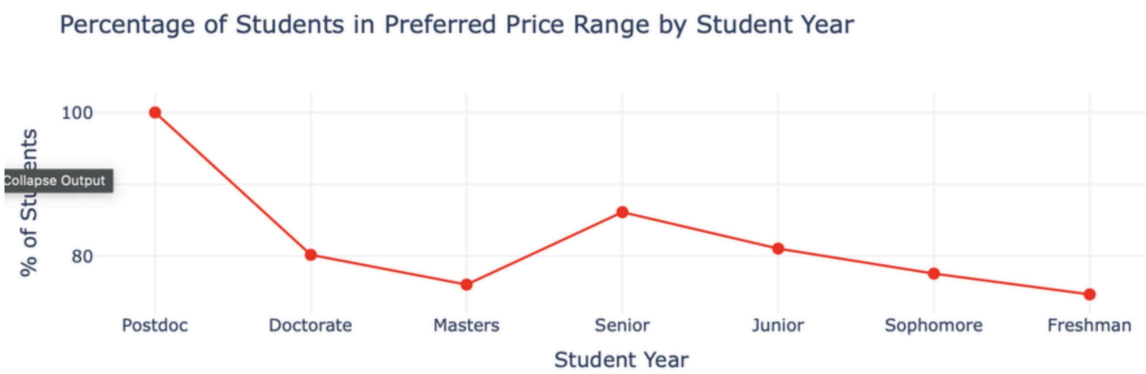
The assessment criteria show that the algorithm put into operation works strongly across various datasets. Between 65% and 79% of students were assigned a room within their preferred price range across Datasets A and C, while approximately 64% to 77% had their private bathroom preferences met. Likewise, satisfaction regarding the availability of laundry services varied between 68% and 79%, while satisfaction with amenities (with at least three amenities) was as high as 78% in certain configurations. The average composite score for students and rooms was between 11 and 12 points, indicating that most students received rooms that were reasonably in line with their stated preferences.

A distinct pattern becomes apparent when results are broken down by academic level. Satisfaction rates are consistently higher among senior, graduate, and postdoctoral students. For example, the success rate for price fit among doctoral and postdoctoral students exceeded 90%, while freshmen averaged around 75%. The difference is deliberate and designed this way. The algorithm applies a credit-based priority system to reward students with more credits and greater seniority, mirroring actual university housing policies. In this context, “fairness” is defined not as uniform outcomes but as predictable prioritization based on established rules. This design benefits senior students, but it may put underclassmen at a disadvantage, as they typically have tighter constraints and less access to premium rooms. This tiered approach, however, preserves transparency and is consistent with the principle of merit-based access.

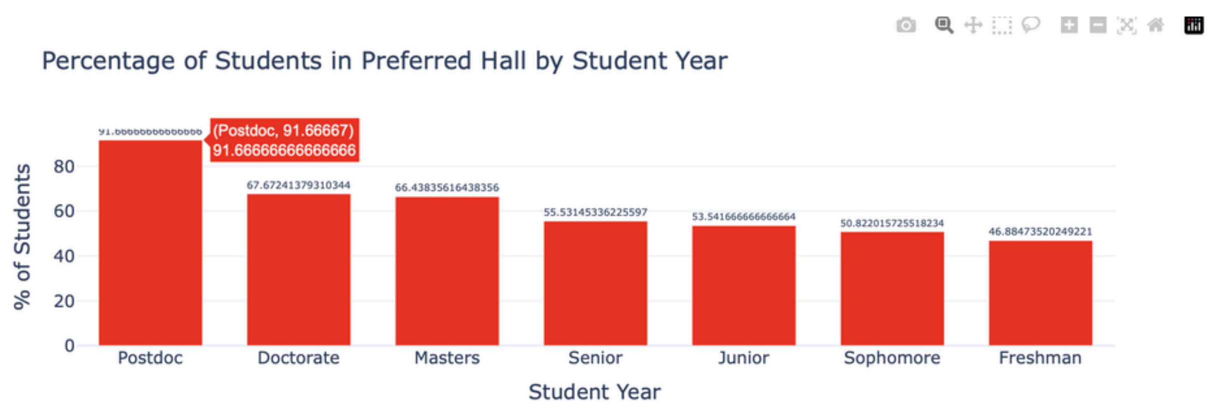
From a fairness standpoint, the findings indicate that although top-tier students gain more from their preferences, each group continues to experience significant satisfaction in relation to at least some aspects (such as amenities or price band). The structure of the algorithm guarantees that no group is punished without justification. Differences arise from the intentional prioritization of academics. All accessibility requirements are adhered to, and the datasets tested contain no violations.

This method offers considerable benefits. This two-stage procedure guarantees that roommate compatibility is maximized prior to the commencement of room assignments, thereby minimizing conflict and enhancing satisfaction of shared preferences. During the Deferred Acceptance stage, instability and favoritism are avoided, ensuring that no unassigned student can swap places to achieve a mutually better result. Furthermore, due to the model's transparency and rule-based nature, it can be easily adjusted. For instance, to place more emphasis on accessibility, affordability, or low-income factors.

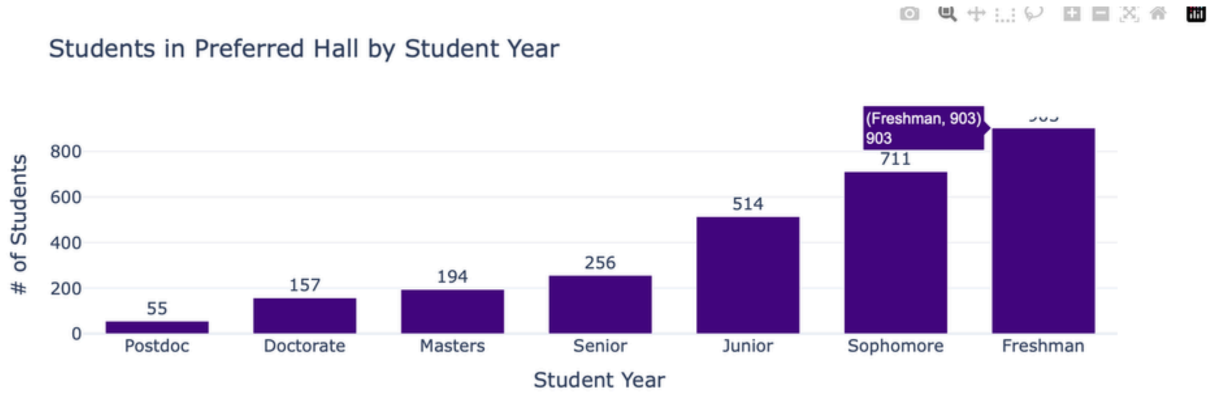
However, the limitations are a lack of capacity and deterministic prioritization. When the number of available or affordable rooms is restricted, satisfaction among these groups decreases significantly. In the same way, due to the fact that seniority is a key determinant, students from lower classes, particularly freshmen, have a reduced probability of being allocated their preferred residence halls or room categories. These outcomes should not be seen as errors, but rather as trade-offs that reflect the realities of policy design. A potential enhancement could involve the addition of reserve quotas based on accessibility or affordability, or the implementation of weighted randomness within tiers to minimize deterministic bias.



The line chart depicts the success of room assignments for students at various academic levels within their preferred price range. It is evident from the trend that postdoctoral and doctoral students reported satisfaction rates that approached 100% and 80%, respectively, while these percentages gradually decreased among undergraduates, culminating in figures of approximately 70–75% for freshmen. This mirrors the algorithm's hierarchical priority system, which gives preference to students with higher credit tiers in room assignment. The pattern suggests that the algorithm is working as intended, giving priority to seniority, while keeping a satisfaction rate for all students that is still relatively high. It does, however, lay bare an equity trade-off. After the allocation of higher-tier rooms, there are fewer affordable options remaining for students who are new to the school.



This bar chart illustrates the number of students at each academic level who were assigned to one of their preferred residence halls. The results demonstrate a comparable trend. Postdoctoral students achieved the highest placement success at 91%, followed by graduate students and seniors, whereas freshmen were at the bottom with an approximate rate of 47%. This result bolsters the fairness rationale built into the algorithm. Students who have been around longer are rewarded with a greater degree of preference satisfaction. This design, while intentional and consistent with policy, reveals a gap in satisfaction between senior and lower-level students. To address this imbalance without upsetting the priority framework, hall diversity could be increased or spaces reserved for first-year students.



This histogram indicates the number of students who successfully obtained rooms in their preferred hall. As anticipated, the number increases with the size of the class; freshmen and sophomores constitute the largest housing cohorts, each comprising 700–900 students, whereas graduate and postdoctoral groups are smaller in number. Although students from lower years show lower preference satisfaction rates, they account for the majority of total assignments because of their larger population size. This confirms that although the algorithm allocates preference fulfillment based on seniority, it still accommodates a significant number of lower-year students overall, ensuring efficient use of available housing capacity.

The results illustrated in the three graphs show that the algorithm attains a well-balanced compromise between fairness by design and system efficiency. Senior students (postdoctoral, doctoral, and master's) consistently achieve higher preference satisfaction as intended, while undergraduates, particularly freshmen, experience lower preference fulfillment but still obtain housing in large numbers. This outcome can be justified from a policy perspective and aligns with algorithmic principles; however, further refinements (such as giving more weight to amenities or affordability for students in their earlier years) could enhance overall equity.

AI Usage

In order to increase our understanding and the standard of our work, we employed AI tools responsibly and appropriately to complete our dorm room assignment project rather than depending on them to complete it for us. AI was mostly utilized as a learning and assistance tool to help us understand coding ideas, solve syntax problems, and make sure our report complied with assignment specifications. For instance, we asked how to efficiently sort or match data, how to leverage graphing libraries like Plotly for visualization, and how to generate and modify dataframes in Pandas. In order to ensure professional presentation, we also employed AI to proofread our written sections for coherence and grammar accuracy. Crucially, our team was responsible for the design, implementation, and analysis of every algorithm.