

A REVIEW OF AGENT-BASED SIMULATION FOR UNIVERSITY STUDENTS ADMISSION

Suha Khalil Assayed and Piyush Maheshwari

Faculty of Engineering and Information Technology,
British University in Dubai, UAE

ABSTRACT

Multiple factors influence college selection and admission behaviors. Most researchers focused on the academic and socioeconomic factors; the academic factors are high school GPA, SAT, admission tests, etc. On the other hand, the socioeconomic factors could be family income and first-generation students, which means parents did not complete their bachelor's degrees. However, some universities admission policies do not pay any attention to the race or to the minorities even though some of them might be from the low-income students which could not afford any admission tests, and they might lose their chance to get admitted into their preferred universities. Therefore, most universities want a fairness admission system that include both the disadvantaged students along with other high-score achievement students. Thus, several simulations have been developed by using the agent-based models in order to simulate a real world system by considering other factors and domains that are varied in the complexities. This paper aimed to review several Agent-Based Models that are deployed by different admission offices from several international universities and colleges around the world, which is classified based on the main contribution of the simulations including the level of educational attainment as well as the universities selection behaviors.

KEYWORDS

agent-based model, abm, netlogo, agents, simulation, disadvantaged students, socioeconomic factors

1. INTRODUCTION

Universities across the world are working hard to compete with other universities globally to attract and host students into their campuses, however quality of education is varying from institution to another, as it depends on multiple of factors such as the quality of teaching, the experience, the environment, and others. Thus, schools and colleges should deploy state of the art technology in order to compete with others effectively (Assayed et al., 2022).

Indeed, some students can see the higher education as part of a long-term investment, according to the Forbes 2022' list of top highest earning, MIT is the highest in the list with an annual salary of \$98,100. On the other hand, many students would not be able to select the best-fit college for them, and accordingly they might start switching the university which could cost a lot of money as many of the completed credits would not be counted. Moreover, the disadvantaged students might not be able to get into their preferred school.

In fact, there are some academic factors could affect students' admission into their preferred universities such as HS GPA, SAT, AP, essays, and extracurricular activities. In addition, some other social factors might affect students' admission like the family income, parent's education, and personal skills. Therefore, a simulation model can play an effective role on simulating the

real world with evaluating the main factors that can affect the universities admission. There are many studies conducted in different aspects of education where the agent-based model was utilized (Nardini et al., 2021; Murphy et al., 2020; Hostetler et al., 2018; Malekipour et al., 2022).

In this paper, a survey was inspected from multiple research papers which used particularly the agent-based models to simulate the university students' admission behavior, and it is organized as following: Section 2 describes previous studies about using the agent-based simulations in taking decision to either study at universities or not, as well as using the simulations for selecting the universities based on students' preference and admission fairness. Section 3 presents the conclusions of these studies, followed by a proposal presented to the readers in section 4.

2. LITERATURE REVIEW

There are multiple socioeconomic factors that have some impacts on the behavior of colleges' decisions, particularly for undergraduate students, thus, some students tend to get admitted into one of the top universities, and others might not be able to go to college after high school, as they could not meet the universities requirements, or they might not even be able to afford it. These concerns have attracted interest from researchers to develop simulation models with different scenarios in order to study the behaviors of student's admission.

2.1. Educational Attainment

Educational attainment is taking the decision whether to study at universities or deciding to not go to 4 -years colleges -after completing high school. The level of educational attainment plays an essential role in providing knowledge and skills to the people in any community (Ching at al., 2022), however, different factors have affected the students who opt to continue the higher education, since many people will select not to go to college after secondary schools, though, there are some papers focused on this particular field, leoni (2021) used an agent-based model in order to explore the factors that influence the college's choice in Italy and for increasing the level of enrollments. The author used the social environment constituted by N from the surrounded neighborhoods of the agents' social connections and relations such as families, friends, and colleagues. As the environment considered the most important part in the ABM where all agents live and interact inside it. Thus, this environment is described as a place where agents live in it and interact between other agents that include rules that can capture the decision-making actions in the real world (Baktash et al., 2022).

The author defined two agents called Junior and Senior agents. Junior agents include those who have completed high school and are looking for either higher education or to drop out, on the other hand, the senior agents are those who are in the labor markets and can be skilled or unskilled, depends on whether they joined the university or not. Junior could choice to enroll in the university if they are influenced by the educational choices of their peers, and in each period of the simulation, the junior agents observe the seniors' neighbors and their choices. Hence, each agent in this model can take an independent decision and this is the main attributes of the agents. However, according to Onggo and Foramitti (2020), agent based model is formed by having a set of autonomous agents that interact in their environment and are able to share as well with other agents based on their behaviors, in order to achieve the objectives. The author used a NetLogo platform. It's a multi-agent programmable modeling environment which is used particularly to simulate the data to better translate the real-world environment. Different parameters tested in the model and simulated into three scenarios depending on their preferences to enroll at universities: 1- expectation in future income 2- The influences from their peers 3- The students' efforts to earn the degrees. The results show that the average of students who enroll in universities are 56%

where the majority of this number (56.2%) comes from parents who own a bachelor's degree (skilled parents).

Interestingly, this topic inspired the economist researchers as well to study the impact of students' welfare to the student's admission behaviors over the time. Carvalho et al. (2019) investigated the relationship between the students allocations in colleges and their welfare. Different scenarios have been explored in different stages by estimating the probability of the success in each school, this model simulated the impact of reducing the number of seats at colleges to the students behaviors as well as the benefits of students admission if the cost of the entry exam is exempted. Though, the model is classified into four stages: 1- school capacities: by defining the quota of each school, and it's denoted by (nj) 2- choice of school: each student chooses only one option of colleges and it's denoted by (m) 3- exam stager: all students taking at least one entry-exam, which denoted by (z) 4- choice of school: all students are ranked based on their grade of entry exam(z), in general this model shows what costs of mechanisms that can be changed in terms of aggregating the benefits of welfare as well as the effected between the students and colleges.

2.2. K-12 Education system

The students and schools' grades prior to the colleges (K-12) have been attracted by the researchers to understand students and parents' behaviors in selecting the schools. The agent-based model can play an essential role in supporting students to choose the best school that can maximize their utilities, Díaz et al. (2021) used the NetLogo 6.0.4 as the development environment that students and schools agents can interact with, together as shown in figure 1. In addition, some attributes are randomly selected in the environment such as the family income, schools' location, as well as schools' performance.



Figure 1. The environment of the model shows the students into different color – based on their income, and the schools as well based on their achievements/ranking

The main contribution of this model is to understand the behavioral of students' selection to schools in Santiago city- Chile, by considering multiple factors such as the family income, school's ranking, location, and school's type (public/private). However, the model is run by triggering different scenarios, for example, when the school-choices turned on, the result shows

that students with high income are enrolling in schools with high ranking and accordingly their GPA are increased as shown in figure 2.

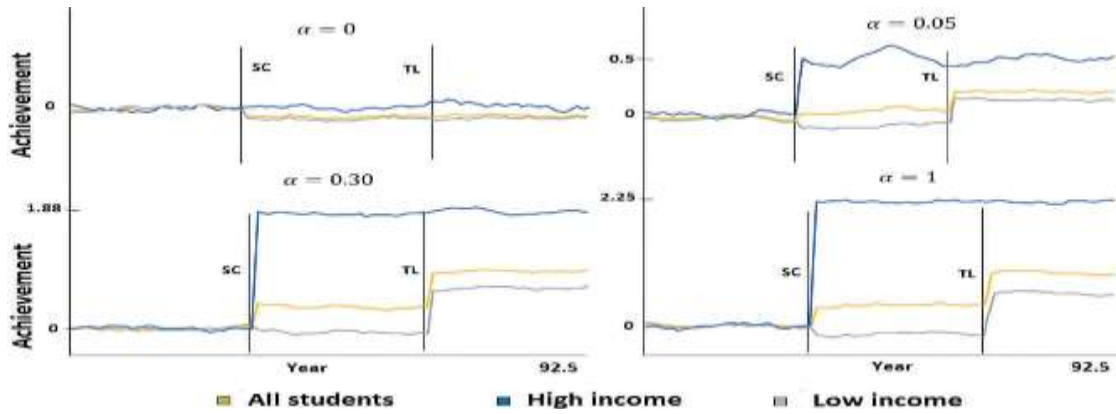


Figure 2. Students GPA achievement based on family-income

2.3. Universities Admissions & Students Preferences

Reardon et al. (2016) used an Agent-Based Model for simulating the sorting process for exploring the family resources' factors that affect the college' choices and acceptance. This simulation aims to understand how the students' attributes and behaviors can influence the sorting of college selection. The authors included two agents (the students and colleges) to simulate the matching process which repeated through 3 stages: 1-applications stage, 2-admission stage 3- enrollments stage as it shows in figure 3.

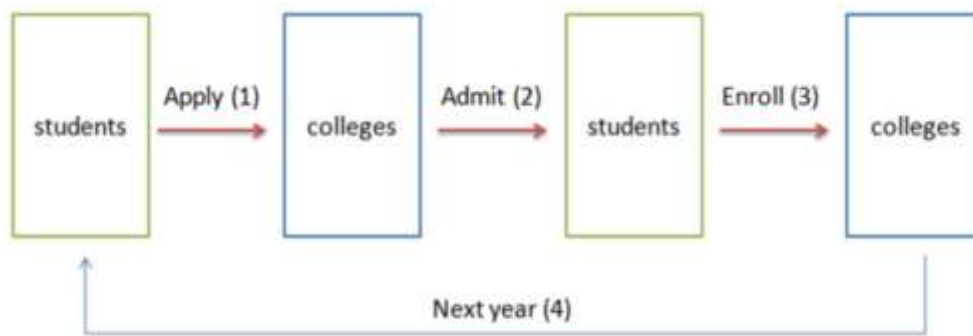


Figure 3. The three stages of the ABM

However, the model linked the students' socioeconomic features to college choices, college costs, financial aid, and other factors are added as well into the model

Thus, students in this model can enroll in the top universities, and at the same time colleges can have the top academic resources (such as SAT/ AP/ HS). As a result, it can predict the probability of student enrollment to the college and attending the top 10% college. However, the authors ran the model 100 times to reach to the examined parameters for evaluating the influence of students' resources to the acceptance rate of universities with minimum biases.

Other Agent-Based Model developed by using NetLogo as simulation environment and the aim is allocating the available seats for students during the admission process (Bhatia, et al., 2015), the students and universities are represented as agents. However, the universities decided the cutoff grades of admission for each particular program, and this cutoff list depends on the past experience of admission for each university based on the high school grades.

The simulation runs in two scenarios: 1-Partially centralized admissions 2- Fully centralized admissions. The partially scenario, all colleges in universities decide their own cutoff list of HS grades for admission to each major. On the other hand, for the fully centralized scenario, each university assigns the seats for their applicants one time after the high schools' results are declared as it shows in figure 4.

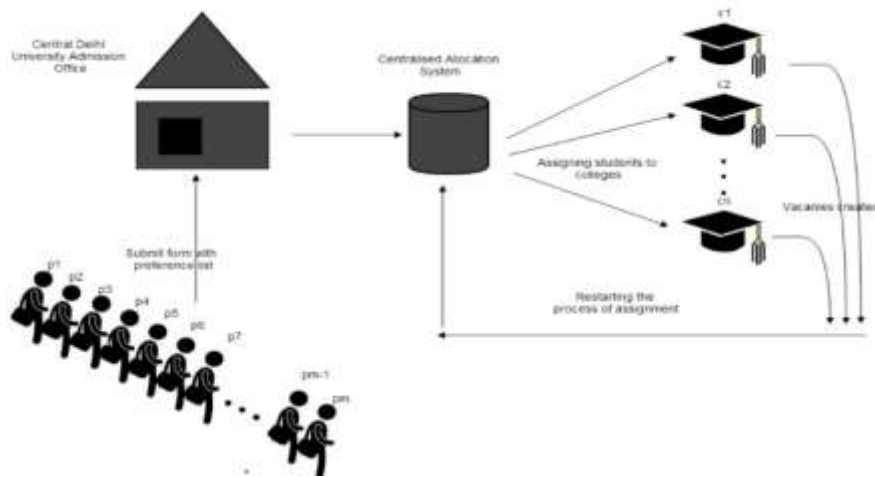


Figure 4. The centralized scenario of universities admission.

The results indicate in this model that colleges that are the most interested in new students might not have the highest cutoff, as the cutoffs mark are generated based on the experience of each college. In addition of that, another Netlogo simulation has been done by Assayed & Maheshwari (2023), the authors used different parameters that affect students' admission into medical schools in Jordan such as the family-income and the high school GPA. Two agents used in this simulation, first agent is the High School Students and the second agent is the Medical Colleges. However, the authors adjusted the number of medical schools in order to study the behavior of universities admission. after several rotations of the simulation the reputation of medical schools are identified based on students' preferences and seats' allocated as it shows that high ranking universities are mainly allocated with have high cut-off GPA score.

Moreover, Hou, et al. (2020) developed a simulation for matching college admission which adopted in Inner Mongolia of China, giving more fairness to the admission system, since students might coordinate together in order to manipulate this mechanism, as students with high scores -at the last minute-, can change the university that they have applied to through the admission system before the deadline, and accordingly a new slot will be opened for a new student with a much lower grade. The author used real-time interactive mechanism by agent-based simulation in multi-stages to study the manipulation behavior of students during the real time by applying different ranges of high school grades to different deadlines for modifying and submitting their applications that can find solutions for the college matching problem. The model defined two agents: student as denoted by $N = (1, 2, 3, \dots, n)$ and university which denoted by $S = (s_1, s_2, s_3, \dots, s_m)$, however the quota of enrollment in each university is denoted by $Q = (q_1, q_2, \dots, q_m)$ which indicates that the number of students that will admit it is q_i , moreover, the preference of students

to select the universities is denoted by $P=(p_1,p_2,..p_n)$, for example $P_i:s_1,s_2,s_3,..,s_m$, which means that, student- i has multiple choices of universities s_1 as first choice, s_2 second choice, etc. Additionally, the ranking of universities might affect the preferences, so this preferences of universities over students denoted by $R=(r_1,r_2,r_3, ..r_m)$, the strategy of this manipulation model depends on the minimum score between two manipulations students (score-diff), as the student can hold a seat for low-score student only if the difference between them is larger than the (score-diff). However, the simulation runs in T rounds, and each student has only one chance to submit the application, but every student should define the basic information of universities that they prefer, such as the ranking, cut-off score and the university's quota, afterward the manipulation-students with high score will apply to universities that accept low scores, and the low score students will apply to the matched universities before the seat-transfer-time, and then the simulation will show how the students with high score will release the seat to the low-score students based on their preferred list and then the high-score students will apply to their preferred university, as well as low-score students will take the seats that released immediately.

Furthermore, Reardon et al. (2017) developed a dynamic simulation to study the changes of socioeconomic status for affirmative action policies on college enrollment choices, in fact, the affirmative action can increase the chances of underrepresented and racial groups students by giving them more consideration to get admitted into top universities. The model used 40 colleges and 150 students for each incoming class, and the totals seats will be 6000. The model limited to the four ethnic groups (White, Black, Hispanic, and Asian), and other factors are considered such as their academic performance (GPA, High school grade, SAT, etc.). The model rotated 3 stages during each simulated year, (application stage, admission stage and enrollment stage), and the results show that the use of affirmative action policies by the colleges can reduce the diversity of same level of colleges that do not have these policies.

3. CONCLUSION

There are different factors that influence the college selection and admission behaviors. Most researchers focused on the academic and socioeconomic factors, for example the academic factors could be GPA, SAT, AP, essays, and extracurricular activities. On the other hand, the socioeconomic factors have a vital role on students' admission such as the inequality in the family income, as it can eventually affect the fairness of allocating the seats during the mechanism of the students' admission. In fact, different simulations have been developed which are varied in the complexities, and most models have two agents, university/college, and the students. Besides of that, all are shared with the same environment which is their community with neighborhood's colleges and universities. However, this review reflects the aim of each simulation from their own perfectives as each country and universities have their own policy in admissions, some of them have the centralized admission system and others might not, besides some countries -such as the USA- use the affirmative action mechanisms in colleges which can increase the likelihood of the disadvantaged students' admission. In addition, the simulation tools that are used in this survey are different, as some models are developed by using the NetLogo environment, others used other statistical techniques, as shown in (Appendix B).

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A: Summary of the Papers Reviewed:

Ser .	Article	Objective	Case Study	Environment	Agents	Simulator tool
1	Bhatia, et al., 2015	Understanding the deferring admission in universities	N/A	Prospected students (higher education)	Students & College	NetLogo
2	Carvalho et al. (2019)	The relationship between the students allocations in colleges and their welfare	N/A	Students communities in	Students & Colleges	Quantitative analysis
3	Díaz et al. (2021)	An agent-based model of school choice with Information asymmetries	Santiago in Chile	K-12 schools/students community	Students and schools	NetLogo
4	Hou, et al. (2020)	giving more fairness to the admission system	Inner Mongolia of China	Students community	Students & Colleges	Quantitative analysis

5	Reardon et al. (2016)	understanding how the students' attributes and behaviors influence sorting of colleges	N/A	Students communities in	Students & Colleges	Regression Analysis
6	Reardon et al. (2017)	Admission with Affirmative action	N/A	Enrollment students at universities	Students & Colleges	Regression Analysis
7	Leoni, S. (2022)	Explain the low educational attainment in Italy	Italy	Neighborhood in students community	Juniors & Seniors	NetLogo

Appendix B: The Journal Quality and Impacts:

Ser.	Author	Title	Journal	Publishes Year	H-Index(SJR)	Quartile(SJR)	Journal Impact Factor(SJR)
1	Baktash et al., 2022	Agent-based modelling for tourism	<i>Current Issues in Tourism</i>	2022	82	Q1	7.43
2	Carvalho, et al.(2019)	College choice, selection, and allocation mechanisms: A structural empirical analysis	<i>Quantitative Economics</i>	2019	29	Q1	1.42
3	Ching, et al. (2022)	Income inequality, educational attainment and environmental degradation: evidence from global panel	<i>Environmental Science and Pollution Research</i>	2022	132	Q1	4.223
4	Díaz et al. (2021)	An agent-based model of school choice with Information asymmetri	<i>Journal of Simulation</i>	2021	26	Q1	1.21

Ser.	Author	Title	Journal	Publishes Year	H-Index(SJR)	Quartile(SJR)	Journal Impact Factor(SJR)
		es					
5	Hostetler et al. (2018)	Unsilencing critical conversations in social-studies teacher education using agent-based modeling	<i>Cognition and Instruction</i>	2018	85	Q1	3.216
6	Leoni, S. (2022).	An Agent-Based Model for Tertiary Educational Choices in Italy	<i>Research in Higher Education</i>	2022	92	Q1	2.98
7	Hou, et al.(2020)	Coordinating Manipulation in Real-time Interactive Mechanism of College Admission : Agent-Based Simulations	<i>Complexity</i>	2020	66	Q1	2.833
8	Malekipoor,A. and Mirjalili,	The Effective Components in the Implementation of M-learning among Student Teachers.	<i>Interdisciplinary Journal of Virtual Learning in Medical Sciences.</i>	2022	N/A	N/A	4.174
9	Murphy et al. (2020)	An introduction to agent-based models as an accessible	<i>Ecology and evolution</i>	2020	75	Q1	2.91

Ser.	Author	Title	Journal	Publishes Year	H-Index(SJR)	Quartile(SJR)	Journal Impact Factor(SJR)
		surrogate to field-based research and teaching					
10	Nardini et al. (2021)	Learning differential equation models from stochastic agent-based model simulations	<i>Journal of the Royal Society Interface</i>	2021	147	Q1	4.293
11	Onggo, et al. (2021)	Agent-based modeling and simulation for business and management: a review and tutorial	<i>IEEE</i>	2021	N/A	N/A	N/A
12	Reardon, et al.(2016)	Agent-Based Simulation Models of the College Sorting Process	<i>Journal of Artificial Societies and Social Simulation</i>	2016	N/A	N/A	2.194