Adapting a COVID-19 Pandemic Simulator to the UT Austin Environment

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***Abstract*—This paper discusses the adaptation of a COVID-19 Pandemic Simulator to the environment of UT Austin. It adds college-specific locations, such as Campus, Parties, Dorms, and Apartments, and reflects the UT population distribution of 55,000 students and 3,000 faculty members. First, an experiment was run on the simulated UT population to determine the infection and critical rate curve for the COVID-19 regulations UT has employed in the past. Then, some modifications to UT's regulations were proposed in order to decrease the number of critical cases: to start implementing regulations earlier, and to take longer to lift regulation. When used in conjunction, these policies decreased UT's critical rate curve by 50%.**

I. Introduction

The emergence of COVID-19 in early 2020 took the world by storm and instantaneously changed people's lives. To minimize the spread of this disease across communities, authorities introduced a quarantine worldwide, mandating stay-at-home orders and shutting down almost everything from schools and offices to bars and restaurants for the first couple of months of the pandemic. As scientists and health professionals discover more things about COVID-19, the government altered its local regulations with the goal of opening the economy back up while still containing the disease as best as possible. There are a lot of factors to consider when making these decisions including the rate of infection in the community, the recovery rate, number of hospital beds available, etc.

Motivated by the challenge of reducing the spread of a pandemic while at the same time also maximizing economic activity, a novel agent-based simulator called the PandemicSimulator [1] was developed to model fine-grained interactions between people in a community. The simulator is an epidemiological model that represents the spread of the pandemic as well as the effects of government lockdown regulations.

The existing PandemicSimulator did not include university campuses among its list of locations in the community. Universities are a unique environment in which there are a lot of people ages 18-23 with vibrant social lives living so closely to each other. Not only did COVID-19 thrive in communities where the population density is high like in a university campus where most students would share their small living space with other students, college students are also notorious for being a breeding ground for germs due to their lack of hygiene. Additionally, because COVID-19 affected the elderly and the immunocompromised at a greater capacity while younger people were expected to recover fairly quickly, many young adults who do not live with an elderly person or immunocompromised people tend to not take as much precaution as others. They believe that getting Covid-19 would just be like catching a bad case of the cold and so many college students still attended social gatherings despite government or school regulations telling them not to. Therefore, we decided that modifying the PandemicSimulator to reflect that of a university environment would be an interesting research project because of how different the lifestyle of college students is and how this can impact the spread of COVID-19 or other pandemic in the future. Specifically, we altered the parameters of the simulator so that the community in the simulation would reflect that of the University of Texas. The goal of this paper is to investigate how the simulator would model the spread of COVID-19 in the university environment and exploring how the University of Texas could have responded better with their COVID-19 regulations during the pandemic to protect its student and staff/faculty members by making more informed decisions about COVID-19 policies and class modality.

The paper will be organized as follows. We will first discuss related work in section 2 and then in section 3 we will explain the changes that we have made to the simulator so that it would be a more accurate representation of the community at the University of Texas. Section 4 presents the experiments that we ran with its results reported and discussed in Section 5. The limitations of the project will be discussed in Section 6 and we will finally end with conclusion in Section 7.

II. Related Work

COVID-19 presented a great challenge for leaders on how to safely reopen offices, businesses, schools, and to allow public gatherings. The topic of reopening colleges and universities soon became a big debate due to the nature of how high contact rates are in a college setting where population density is high. A group of researchers from Stanford published a data-driven modeling study that showed how college campuses are superspreaders [2]. The paper studied the dynamic reproduction number for 30 institutions using each of their published daily case reports by combining a mathematical epidemiology model and Bayesian learning. Within the first two weeks of starting in person class, 14 out of the 30 campuses showed a tremendous increase in infections with

its peak seven-day incidences 1,000 to 100,000 times larger than the nation-wide peaks during the first and second waves of the pandemic. A study investigating multiple COVID-19 clusters on a university campus cite that student gatherings and congregate living settings on and off campus are to blame for the rapid infections within the community [3]. Even though young adults are not in the high risk category for COVID-19 and most college-aged people are able to fully recover from it, it is still important to mitigate the spread of COVID-19 in college campuses because the paper [2] also found that many failed to control the spread of the virus beyond their own campus despite the data proving that most schools were able to quickly reduce the number of new infections. For this reason, it is important that we consider the implication of large college outbreaks and how it can impact those at a greater risk from developing serious symptoms from COVID-19 who live in the surrounding communities of the campus and how robust measures are needed to reduce transmission in college campuses.

The PandemicSimulator [1] is a simulator that is able to model fine-grained interactions among people at specific locations in a community. Additionally, the simulator also included a reinforcement learning-based methodology for optimizing fine-grained mitigation policies. The simulator was developed by AI researchers and epidemiologists that takes into account real-world factors such as false positive and false negative tests, contact tracing, variable spread rates in infected people, and how closely the general community adhere to the social distancing guidelines imposed. PandemicSimulator is therefore tool that can be used to study the circulation of a disease and how different regulations enacted by the government could effect the spread of said disease. The functional blocks of the PandemicSimulator include locations, people, an infection model, an optional testing strategy, an optional contact tracing strategy, and a government that makes policy decisions.

III. Technical Approach

To change the environment of the simulator to more closely model that of University of Texas, we implemented changes to the population distribution, the living accommodations of UT-affiliated individuals, and the places they most frequent. The modifications that we have implemented are as follows.

A. Location

1) *Campus*
The school location represented in the original simulator reflects a k-12 school since only minors were assigned to these schools. We changed the implementation of the school class so that each campus class represents a building in UT. In total there are 103 buildings on campus [4]. We set the open times for each building to be from 7 AM to 7 PM during the weekdays since that is the unrestricted hours for most buildings on campus. We did not handle the case for the unrestricted hours because during those hours there would be very few people on campus buildings which would make it easier for people to social distance and make contact rate negligible for the purposes of the simulator. We set the contact rate for campus buildings to be higher than the original school in the simulator because college students spend more time on campus buildings not only for classes and labs but also for studying with groups and events held by different student organizations. Furthermore, despite the university's effort to impose a social distancing guidelines in classrooms by requiring students to leave empty seats between other students, no one actually enforces social distancing guidelines outside of classrooms so students were still interacting closely with other students in the common areas of campus buildings.
2) *Hybrid Campus*
This served as an implementation of Campus, but in Hybrid mode. The Hybrid Campus buildings worked like toggle switches corresponding to the level of COVID regulations UT was currently enforcing. In less restricted stages of lockdown, Hybrid Campus was kept open. However, as soon as lockdown started to enter higher stages, Hybrid Campus represented the classes that were moved online during high levels of COVID, and was locked as a location.
3) *Dorms*
According to UT Austin's University Housing and Dining catalog, at full capacity, about 14% of the total student population lives in on-campus dorms [5]. In order to simulate these on-campus living accommodations, we partitioned 14% of the student population to live on campus, and then clustered them into groups of 30, to represent one floor of a dormitory, since students on the same floor usually interact at the same level as members of a family in a house – communal bathrooms, shared dining halls, etc. The only thing that is completely private is a bedroom, and even that is often shared with a roommate. We set dorms to have the highest contact rate out of all the housing options.
4) *Apartments*
The remaining students were assigned to apartments to represent off-campus accommodations, which apply to approximately 86% of the UT student population. In order to accurately represent the conditions of off-campus student housing, we clustered students into groups of 2-5, since that's the range of roommates students normally live with. These Apartments were kept separate from the faculty housing, since faculty normally live far from campus, and from dorms, which are located on campus and normally function much differently compared to apartment buildings. Apartment buildings were set to have the second highest contact rate since it still involved living in a building with hundreds of other people and potentially sharing elevators, gyms, etc, but normally bathrooms and kitchens are private.
5) *Parties*
We added a new location type, parties, since parties are a big aspect of social gatherings for college students.

In our UT simulator, parties include large gatherings held by Greek life, parties held at different people's apartments, and sporting events such as tailgating. An article written by CNBC [6] showed how COVID-19 spikes on college campuses are closely correlated to parties. The article reported that nearly half of college students who were back on campus Fall of 2020 still went to parties despite social distancing guidelines and 20% of them tested positive for COVID-19. The article also reported that 5% of students refuse to get tested or self-quarantine if they found out that a person who attended the same party they went to tested positive. We implemented the party class so that the attendees of the party would have a high contact rate since people who attend parties would in general not wear masks and people would be in very close proximity with other people at a party which means that the risk of COVID-19 transmission would be high.

6) *Bars*
Bars is already a location type available on the simulator. One change that we made to the existing Bar class implementation is lowering the age limit from 21 to 19. The reason for this is because even though the legal age to drink alcohol in the United States is 21, many freshmen and sophomores still go to bars using fake IDs. According to a study [7], out of 3,720 undergraduates who were assessed from the summer before their freshman year to the end of their fourth semester, fake ID ownership increased over time from 12.5% before entering college to 32.2% by the end of their fourth semester and that Greek society members were more likely than other to own fake IDs. Because Greek life culture is quite prominent in many universities in America, including UT, based on this study [7] we believed it is justifiable for us to decrease the minimum age limit for bars to simulate underage drinking and how this can help the spread of COVID-19.

B. People

UT Austin has a student body population of approximately 52,000 and a faculty population of approximately 3,000 [4]. In order to be able to simulate a population of any size, we created a distribution made up of 95% students and 5% faculty members.

1) *Student*
The simulated UT student population was uniformly distributed across ages 18 to 24 in order to account for both undergraduate and graduate students. Students were randomly assigned both their classes (with an equal chance of being placed in Campus or Hybrid Campus) and their living accommodations (with a 14% chance of being placed in a dorm and an 86% chance of being placed in an apartment, with a uniform distribution of 2-5 roommates across all the apartment units). Students were also given a custom compliance rate of 0.6, in comparison to the original compliance rate of 0.99, since historically, college students are much more likely to flout COVID regulations.
Student routines were comprised of going to school between the hours of 9 AM to 5 PM since that's when most classes are held. After school, they would complete their "social routine" which was made up of visiting restaurants, bars, parties, or friends' apartments. They visited the grocery store and retail stores one a week. Their weekend routine consisted of restaurants, bars, and parties, with a much higher explore probability than faculty.

2) *Staff and Faculty Member*
The simulated UT faculty population was normally distributed across ages 25 to 90 in order to account for faculty at all levels. Faculty were randomly assigned their homes (clustered into groups of 1 or 2, since most faculty do not live with any other UT-affiliated individuals, but some do) and were randomly assigned into the classes and buildings they teach in (with an equal chance of being placed in Campus or Hybrid Campus). Faculty members were assigned the original compliance rate of 0.99% since they are more likely to follow COVID-19 measures, especially if they're being mandated by the University.
Faculty routines were comprised of going to campus between the hours of 9 AM to 5 PM since that's when most classes, office hours, and staff meetings are held. After work, they would complete their "social routines" which consisted of going to restaurants and bars, before returning home. Since this simulator is treating UT as a closed system, we did not simulate the faculty member's non-UT affiliated family members, such as another adult or any kids sharing their living accommodations. Faculty members would also head to grocery and retail stores once a week, and went to restaurants during weekends.

C. COVID-19 Regulations

In order to better reflect UT COVID-19 trends, we needed to apply University-specific regulations. This involved mirroring the stages that UT Austin and West Campus went through during the past 2 years as restrictions and quarantines were gradually lifted in stages, as well as accounting for the reckless behavior of young people.

1) Transformation of COVID-Regulation Stages: The original Pandemic Simulator included COVID-19 regulation stages from 0 to 4, with 0 being the behaving regularly and 4 being complete lockdown. However, since we've adapted the simulator to reflect UT-specific regulations, independent of government COVID rules, we have made alterations to the regulation system.

- Stage 0: No UT restrictions. All classes are in person, all restaurants are open.
- Stage 1: Students wear facial coverings, but all classes are still open.
- Stage 2: Social locations remain unlocked, however half the classes go online, since hybrid campus is now locked.

- Stage 3: Bars go on lockdown as well since they are popular gathering events for students, and often COVID-19 hotspots.
- Stage 4: Everything is locked and all classes are moved online. Social locations and non-essential businesses have gone remote.

2) Contact Rate, Social Distancing, Compliance Rate: Many parameters were altered to account for the behavioral trends of young people. For example, the contact rate was increased immensely from the original Pandemic Simulator values, since bars, restaurants, and parties are are much more crowded in college towns than in non-college areas. The minimum number of contacts between visitors and assignees, assignees and assignees, and assignees and visitors were all increased to account for how many people a student runs into during their social or weekend routines.

Additionally, parameters in the COVID-19 regulations were decreased, such as hygiene, social distancing, and compliance rate. It's well-known (albeit anecdotal that college students have poor hygiene due to stress and lack of motivation), so we changed the "practices good hygiene" to false for many of the stages of UT regulations. Along that same vein, we reduced the rate of compliance, since college students are more likely to flout COVID restrictions than middle-ages people, since they are less likely to face severe medical consequences. Students are also not likely to stay home when sick, since staying home often means missing assignments and having to email professors for accommodations.

Social distancing was set to default for all levels of restrictions besides the strictest one because when things are still in-person and restaurants are still open, it's difficult to maintain adequate social distance. Nearly all student spaces are crowded all of the time, especially at a university as large as UT Austin. The "risk factor of attending large gatherings" for each student was decreased, since students would have much more liberal thresholds for what is considered a party or social gathering too large to attend.

3) Hybrid Campus: One of the modifications we proposed was the option to have half the locations of a particular type close, such as buildings on campus. This was especially applicable during Fall 2021 and Spring 2022, in which classes were not fully in-person yet, but were not fully online either.

We implemented this through the addition of "Hybrid Campus" buildings, which represent the classes that move online when COVID-19 restrictions are high. Hybrid campus buildings are identical in every way to campus buildings, the only difference is what stage of restrictions it gets locked at. Both students and faculty are randomly assigned to all campus buildings, with an equal probability of getting a campus or a hybrid-campus building.

IV. Experiments

A. Mimicking UT Austin COVID-19 regulation strategies

In order to get a baseline for the population infection rate and locations that are serving as COVID-19 hotspots, we programmed the simulator to run with the progression of restrictions that UT enforced from the Spring 2020 to Fall 2022 Semesters. Additionally, we prevented the simulation from going all the way to Stage 4 to account for how even during the strictest COVID restrictions, students are still seeing each other, since the restrictions are UT-enforced and not governmental in nature.

- Spring 2020: Stage 0 for 90 days, and then immediate jump to Stage 3, when UT went through quarantines and shut down campus in March 2020.
- Fall 2020: Stage 3 continues, all classes are online.
- Spring 2021: Stage 2, classes are still online but some students are back on campus
- Fall 2021: Stage 1: Classes are mostly hybrid and everyone is back on campus and participating in social events.
- Spring 2022: Stage 0: Classes are back in person and everyone is living normally.

B. First improved policy strategy: Earlier Response

Our first strategy to try and improve the UT COVID infection and critical rate curves was to try and implement COVID restrictions earlier. According to the CDC, February 10, 2020 was when the worldwide deaths from the 2019 Novel Coronavirus reach 1,013. The SARS-CoV-2 virus had then killed more people than the severe acute respiratory syndrome (SARS-CoV-1) outbreak [8]. We wanted to see if the infection rate of the UT population would change had UT decided to gradually implement restrictions then, rather than when a worldwide emergency was declared.

In order to simulate this, we included a couple weeks of Stage 0, followed by a gradual build: a couple weeks of stage 1, a couple weeks of stage 2, and finally, stage 3. Then, the UT restrictions progress as normal, by semester, as described in the above section.

C. Second improved policy strategy: Longer Periods of Restrictions

Our second strategy to try and improve the UT COVID infection and critical rate curves was to try and implement COVID restrictions for longer. Although we spent one semester at Stage 3, before lessening restrictions every semester, COVID was still a prominent problem and continued to spread among the UT population. We wanted to simulate the maintenance of Stage 3-level UT COVID restrictions across 2 semesters, followed by a descent to stage 1, and then finally stage 0.

V. Results

Throughout the 500 days period, figure 1 shows that most of the infections occurred on campus, while the second most infection occurred in apartments and dorms. Less infections occurred at parties. This means that the main source of infections was campus due to the amount of students on campus during working hours, and that infections were mostly transmitted to other students in the same building, as well as roommates. Large amounts of students living, working, and partying together is one of the main contributors for

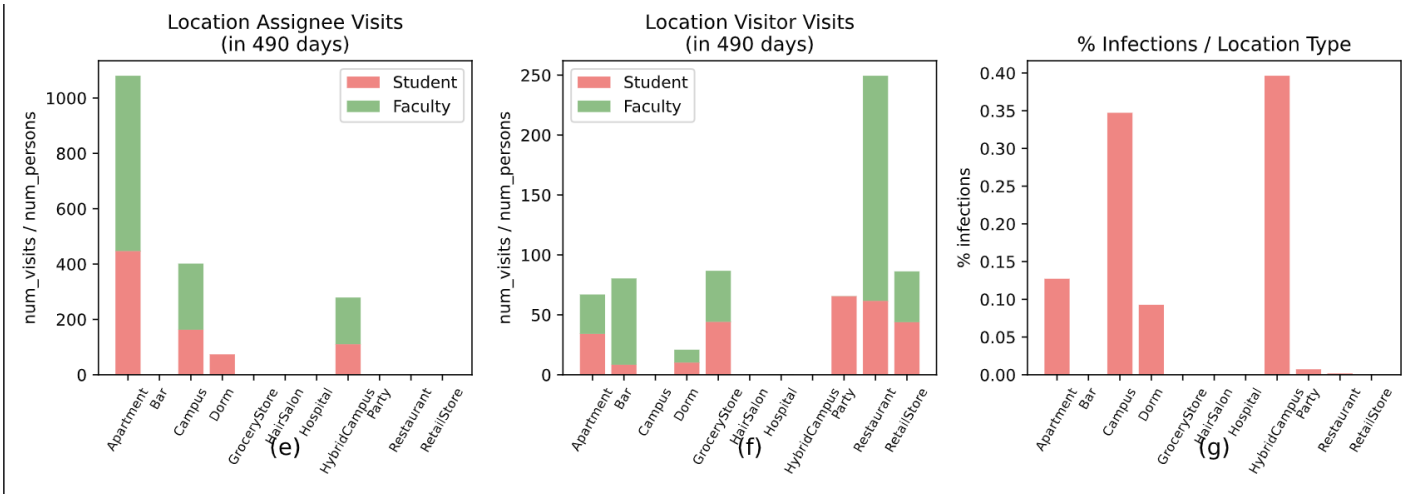

Fig. 1. Number of visits for each location and the percent infections per location type

college campuses being ”superspreaders”. Although the rate of infection in figure 2 stayed them same across the board, the number of critical cases decreased while employing the experimental strategies.

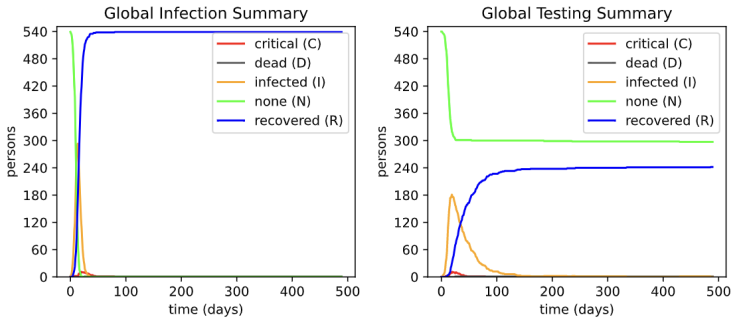

Fig. 2. The infection summary and the testing summary for the UT community

A. Mimicking UT Austin COVID-19 regulation strategies

Figure 3 shows the summary of critical cases while simulating UT's real regulations from 2020-2022. The number of critical cases surpasses the maximum hospital capacity about 40 days in. The experimental improvements are meant to ensure that the number of critical cases stays beneath the maximum hospital capacity.

B. First improved policy strategy: Earlier Response

For our first experiment, we implemented earlier gradual COVID-19 regulations, to simulate what would have happened had UT started COVID restrictions in February. This time, the critical summary result in figure 4 demonstrates a peak of 7 critical cases, which is still firmly below the maximum hospital capacity.

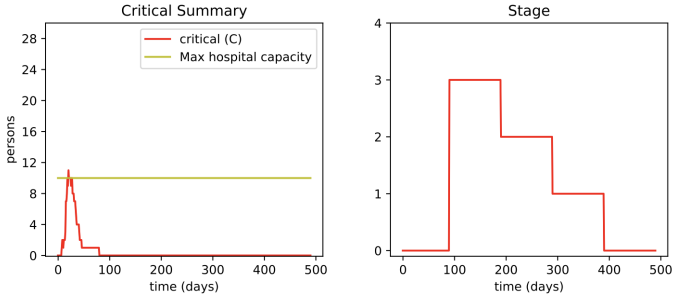

Fig. 3. The critical summary result for UT Austin's COVID-19 regulation strategies

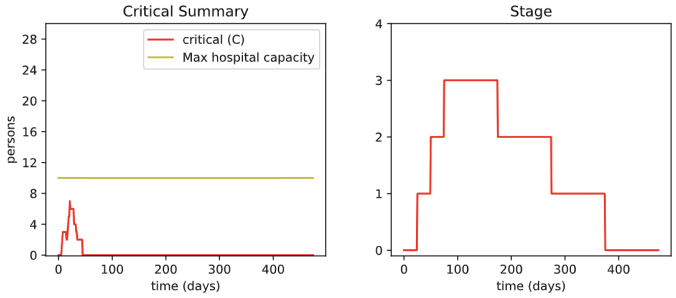

Fig. 4. The critical summary result if UT started to place restrictions earlier in the semester

C. Second improved policy strategy: Longer Periods of Restrictions

For our second experiment, we combined the earlier gradual restrictions with an extension of the stage 3 period, simulating if UT would have maintained Stage 3 restrictions into Spring 2021. With this combination of strategies, the critical summary curve dropped even further, with a peak at about 5 cases as seen in figure 5. This combination proved to be the most successful out of the 3 in terms of ensuring that the number of critical cases never surpasses the maximum hospital capacity.

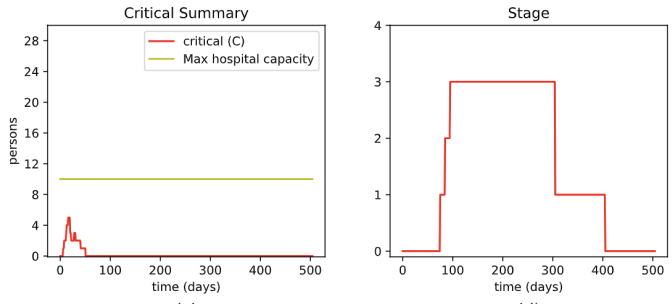

Fig. 5. The critical summary result if UT imposes a stage 3 restriction for a longer period of time.

VI. Discussion

Although the original Pandemic Simulator was altered in this paper to represent the UT Austin student and faculty populations and activities, there remain some limitations of this study.

First, this simulation does not take into account vaccinations or boosters. Had vaccinations been implemented as a parameter, the curve likely would have seen different patterns, as vaccines lose their efficacy.

Second, this simulation does not take into account new variants of COVID-19, which emerged every couple months with new challenges and infection rates.

The proposed strategies for improving the number of critical cases involved tuning hyperparameters and looking at the results. Perhaps a more efficient policy for future use is taking into account real COVID data from the UT Austin population and optimizing a strategy to flatten the curve using reinforcement learning.

For the purposes of simulation, UT is currently treated as a closed system, however that's a bit of an oversimplification. There are people who aren't students or faculty who interact with them, such as family, service workers, visitors from out of town, etc. Currently, when everyone in the UT community has recovered from COVID, the simulator no longer depicts COVID as a threat, however, in real life, a visitor could always bring it back.

Finally, the simulator is not fully calibrated for UT Austin. For the purposes of abstraction and computational power, we reduced the number of people at UT Austin from 55,000 to 550.

Additionally, while this simulator can allow for safer COVID-restrictions campus-wide, it also has some potentially negative consequences. For one, college students tend to value a return to normalcy over staying completely safe from COVID-19, due to their rates of recovery, and the priorities of this simulator and this study may not align with that of students. If this simulator leads to UT implementing stricter COVID lockdown strategies, this may negatively impact students who want to have a normal semester in-person.

Another potential consequence is UT policymakers using this simulator in order to decide to limit class sizes further in the event of a potential oncoming pandemic. This could detrimentally affect students who are already struggling to register for the classes they need as graduation requirements.

VII. Conclusion

The COVID-19 pandemic was a devastating world health-crisis that lead to widespread infection and subsequent quarantining. College campuses were infamous for being "super-spreaders" of COVID-19 due to the close proximity in which students lived and worked together. In this study, we adapted a COVID-19 Pandemic Simulator to reflect the environment of UT Austin by altering the locations, population distribution, living accommodations, and everyday schedules, as well as altering covid restrictions to be UT-specific historically accurate COVID restrictions.

While implementing the restriction policies that UT did over the same duration, there was a brief spike of critical cases above the threshold of the maximum hospital capacity. Two improvements were proposed to the COVID-19 strategy: to start it earlier next time, and to wait longer to loosen restrictions. The first strategy reduced the number of critical cases by almost 25%. The second strategy, added on top of the first, reduced the number of critical cases by 50%.

It's important to understand these trends in the context of a college campus, where students live closer together, are less likely to comply with COVID restrictions, and have more active social lives. By implementing better strategic policies, we can optimize pandemic policies at universities for any future health-crises.

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