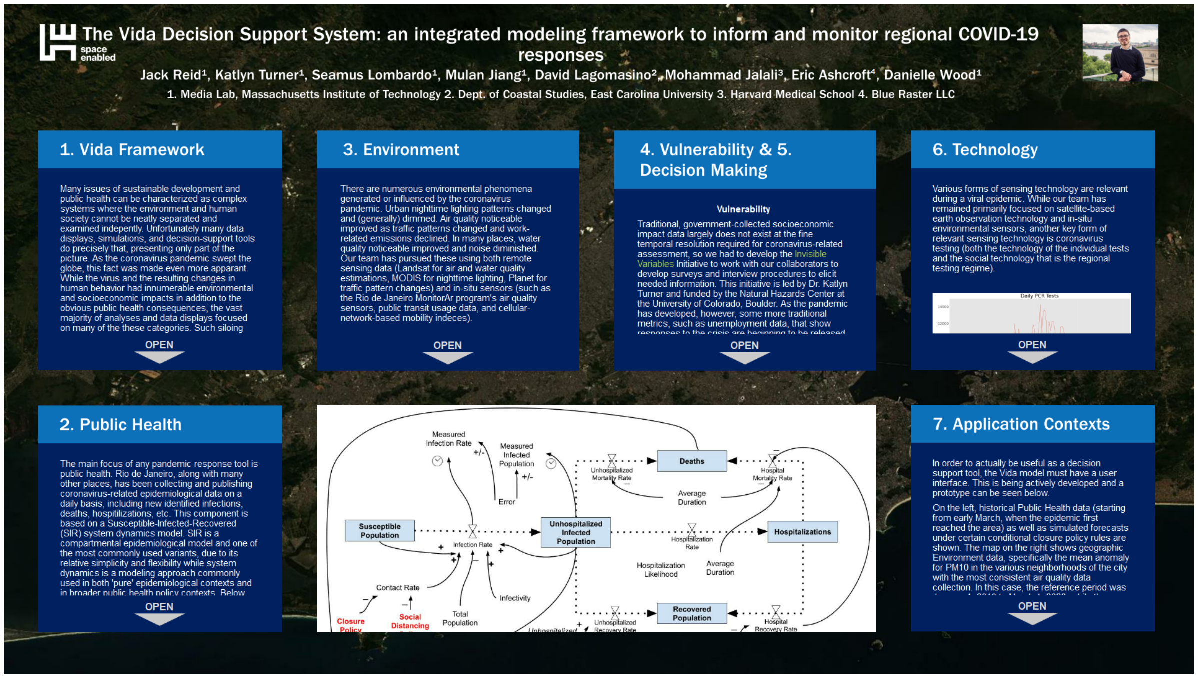
# The Vida Decision Support System: an integrated modeling framework to inform and monitor regional COVID-19 responses

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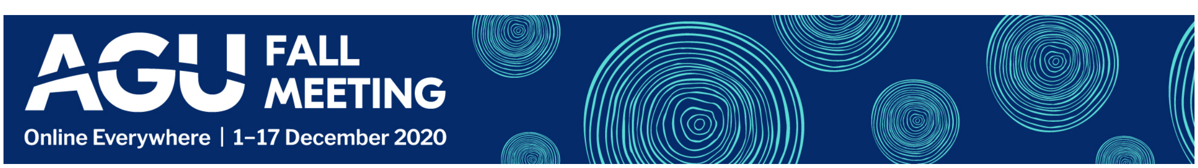
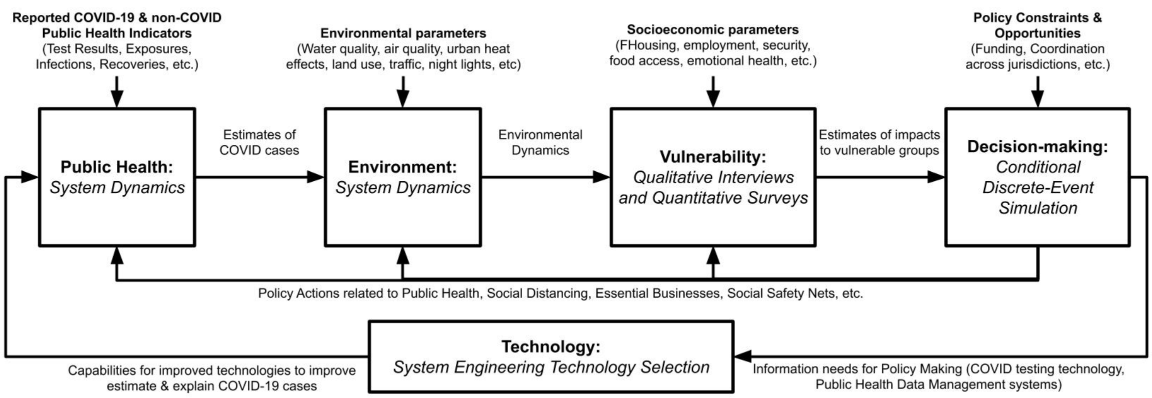


# 1. VIDA FRAMEWORK

Many issues of sustainable development and public health can be characterized as complex systems where the environment and human society cannot be neatly separated and examined indepently. Unfortunately many data displays, simulations, and decision-support tools do precisely that, presenting only part of the picture. As the coronavirus pandemic swept the globe, this fact was made even more apparant. While the virus and the resulting changes in human behavior had innumerable environmental and socioeconomic impacts in addition to the obvious public health consequences, the vast majority of analyses and data displays focused on just one of the these categories. Such siloing misses important cross-domain causal links and consquences, thereby hindering effective decision-making abilities.

In order to recify this, Space Enabled Research Group at MIT has been working with to advance a interdisciplinary modeling framework to approach coronavirus-related decision-making and impact analysis. This of course requires a multi-dispinary team, which is why Space Enabled has partnered with relevant experts, including public health expert Dr. Mohammad Jalali (Harvard Medical School), earth scientist Dr. David Lagomasino (East Carolina University), and data analytics expert Eric Ashcroft (Blue Raster LLC).

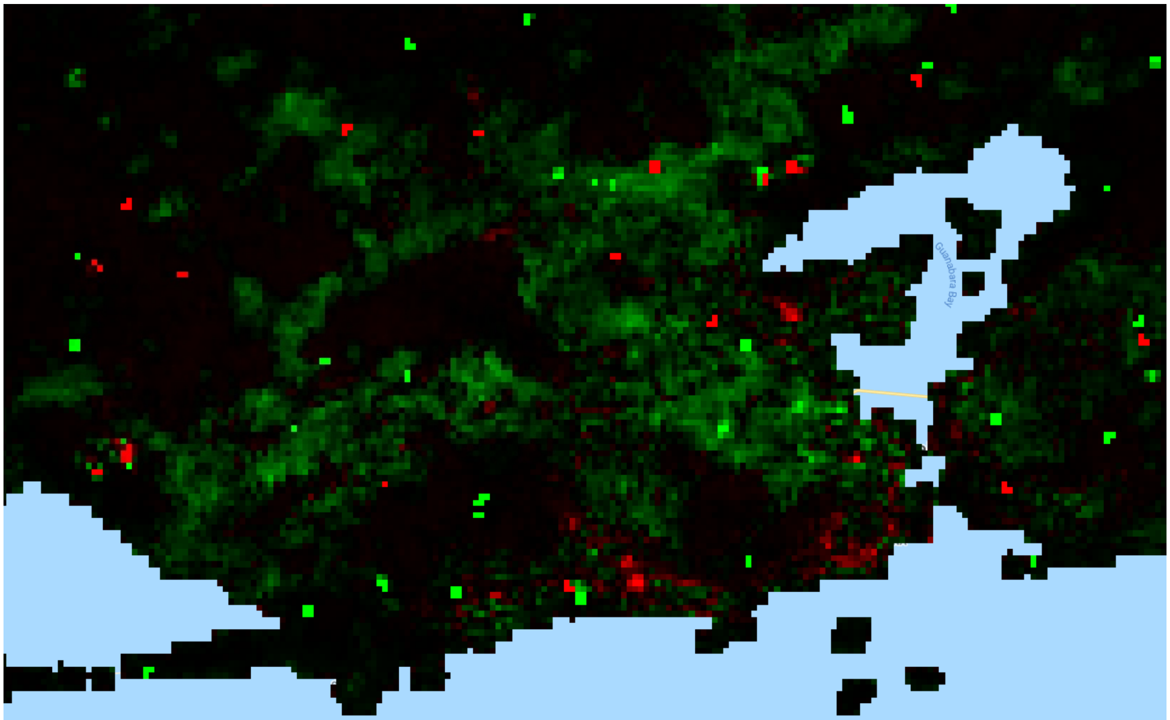
The framework that we developed is called the Vida Decision Support System. The goal of Vida is to create an accessible and openly available online platform that can be customized by the leadership team for a city or region and bring together knowledge from several areas of expertise. The five components of Vida, each of which serve to model a specific domain, include Public Health, Environment, Socio-economic Impacts, Public Policy, and Technology.



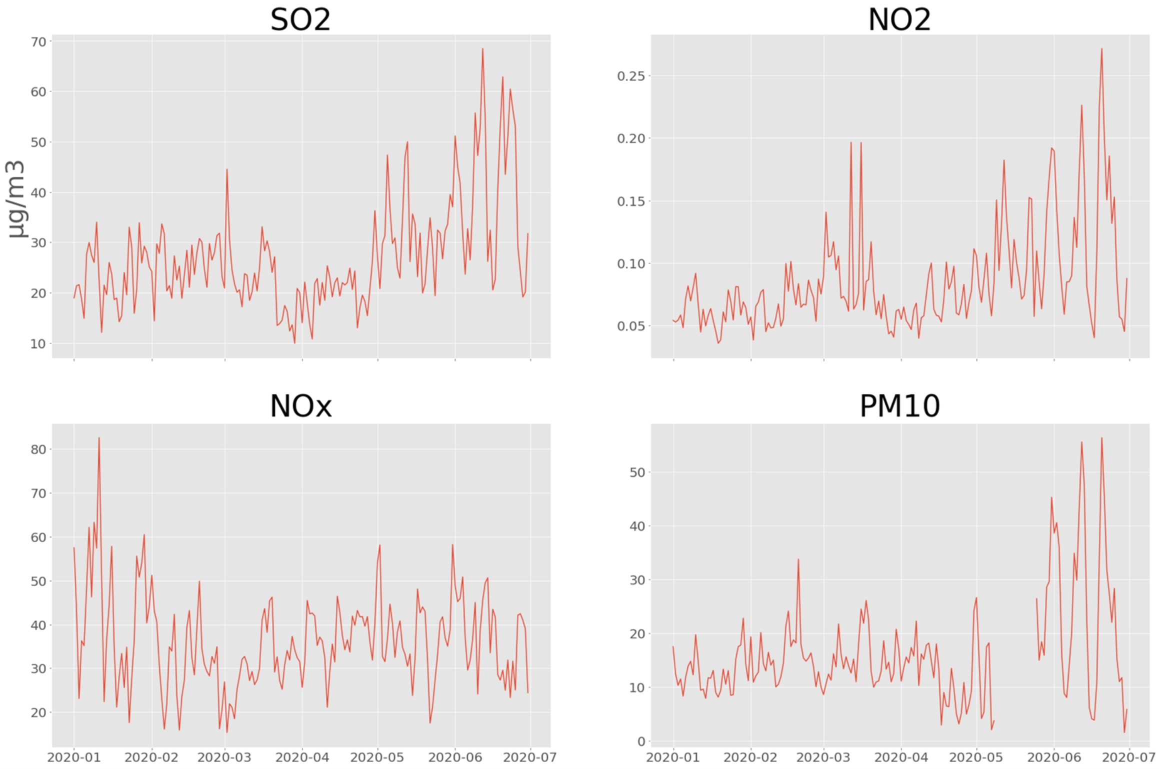

The environmental data comes from sources such as in-situ sensors and both civil and commercial earth observation instruments (Landsat, VIIRS, Planet Labs' PlanetScope, etc.) to track factors such as water quality, forest extent and health, air quality, human mobility, and nighttime urban lighting. Similarly, socioeconomic data derives from both in-situ sources, such as local statistical agencies, and from satellite products, such as those hosted by NASA's Socioeconomic Data and Applications Center. The remaining sections go into more detail on each of these components, focusing on the city of Rio de Janeiro, Brazil, as a case study.

# 3. ENVIRONMENT

There are numerous environmental phenomena generated or influenced by the coronavirus pandemic. Urban nighttime lighting patterns changed and (generally) dimmed [4]. Air quality noticeably improved as traffic patterns changed and work-related emissions declined [5]. In many places, water quality improved and noise diminished [6]. Our team has pursued these using both remote sensing data (Landsat for air and water quality estimations, MODIS for nighttime lighting, Planet for traffic pattern changes) and in-situ sensors (such as the Rio de Janeiro MonitorAr program's air quality sensors [7], public transit usage data, and cellular-network-based mobility indeces).



Above you can see mean anomaly of nightlight data in Rio de Janeiro comparing the average nightlight brightness for the first three months of the pandemic compared to the pre-COVID average nightlight levels. Green indicates areas that brightened, while red indicates areas that dimmed. The primary residential areas of the city all brightened, while the main tourism sectors of the city (southern coast), the international airport (northeast of the city), and some steel plants (northwestern corner of the city) all dimmed.




Here you can see daily average air pollutant levels for the city, based on 8 in-situ sensors. Analysis to understand the extent to which coronavirus has impacted these pollutants, both across the city and in specific neighborhoods, is ongoing.

Air quality and mobility changes can help provide insight into the behaviors of the populace beyond the current policy status. These insights can help to estimate such values as the average contact rate between individuals, thereby improving the public health model shown in the previous section.

# 4. VULNERABILITY & 5. DECISION MAKING

**Vulnerability**

Traditional, government-collected socioeconomic impact data largely does not exist at the fine temporal resolution required for real-time coronavirus-related assessment, so we had to develop the Invisible Variables (https://www.media.mit.edu/projects/invisible-variables/overview/) Initiative and have been working with our collaborators to develop surveys and interview procedures to elicit needed information. This initiative is led by Dr. Katlyn Turner and funded by the Natural Hazards Center at the University of Colorado, Boulder. You can see more information about this on the Virtual Poster titled "The Impact of Social Distancing Policies on the Lives of Individuals from Vulnerable Job Sectors in Greater Boston."

As the pandemic has developed, however, some more traditional metrics, such as unemployment data, that show responses to the crisis are beginning to be released. These are being actively incoporated into the Vida analyses.


**Decision-Making**

Obviously the primary decision axes are containing the spread of coronavirus and properly treating those who are infected. In practice this tends to express itself as various forms of public area and business closures and restrictions, individual social distancing requirements (such as mask wearing), and medical equipment acquisition and allocation. In Rio de Janeiro, many of these policies have been grouped together into a six phase Resumption Plan that has clear indicator-based conditions for when to advance to the next phase [8], which facilitates visualization and simulation in Vida.

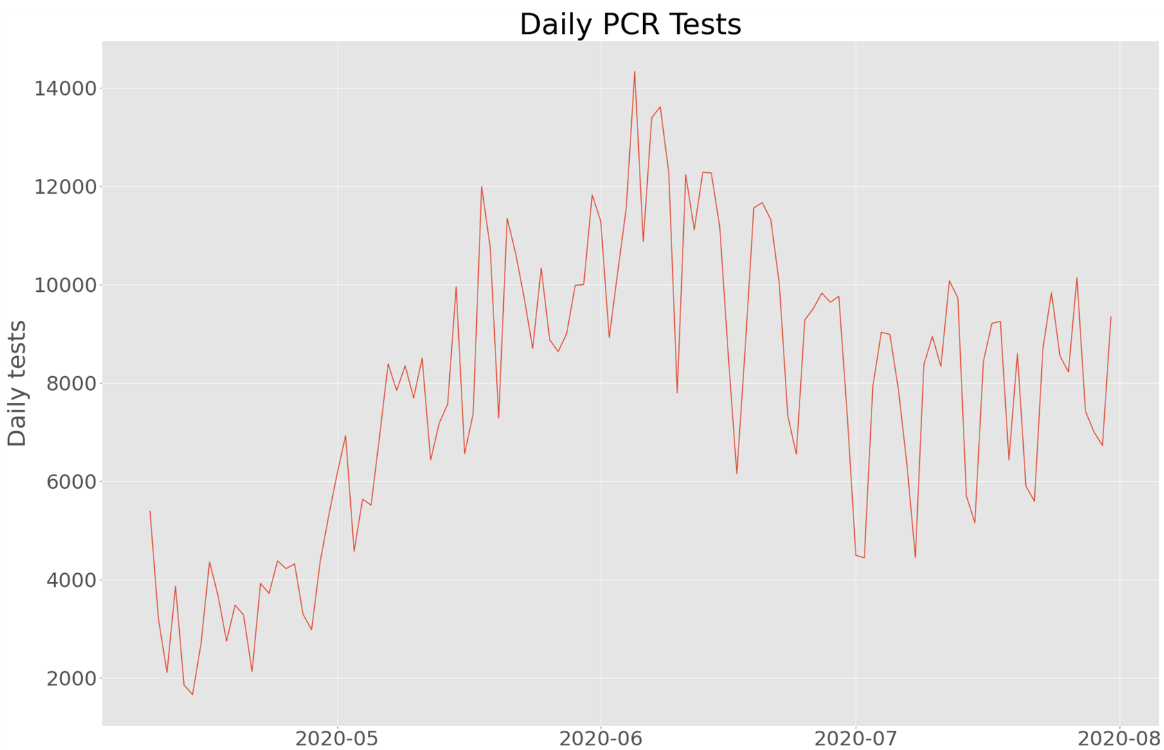
## Recovery Plan Indicators

updated on 11/15/2020

| Reference Date | 11/14/2020 | | | Comparison with previous days | | | | | | 09/30/2020 | 11/14/2020 | WE ARE IN THE CONSERVATIVE PERIOD SINCE 11/3/2020 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GROUP | ANALYSIS PARAMETERS | PRIMARY INDICATORS | | F-1 | D-5 | D-4 | D-3 | D-2 | D-1 | Ref. Previous Phase | Result | PHASE 1 | PHASE 2 | PHASE 3 | PHASE 4 | PHASE 5 | PHASE 6 |
| HEALTH SYSTEM RESPONSE CAPACITY | Capacity of ICU beds | 1 | Percentage of occupancy of dedicated adult ICU beds COVID (ICU SRAG) METRO I SUS bed (7-day moving average) | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | 80.7 | 81.0 | Favorable | Favorable | Favorable | Favorable | Favorable | Favorable |
| | | two | Occupancy rate of supplementary sector ICU beds (moving average 7 days) (a) | ✗ | ✓ | ✓ | ✓ | ✓ | ✗ | 76.4 | 79.1 | Favorable | Favorable | Favorable | Favorable | Favorable | Favorable |
| | | 3 | Percentage of occupancy of life support beds REDE SUS Territory of the municipality (moving average 7 days) | ✗ | ✗ | ✗ | ✓ | ✗ | ✗ | 85.4 | 88.9 | Favorable | Favorable | Favorable | Favorable | Not Favorable | Not Favorable |
| | | 4 | ICU COVID beds (REDE SUS) per 100k inhabitants (b) | ✓ | ✓ | ✓ | ✓ | = | ✗ | 5.20 | 5.25 | Favorable | Not Favorable | Not Favorable | Not Favorable | Not Favorable | Not Favorable |
| TRANSMISSION LEVEL | Variation of deaths | 5 | Death Variation Rate by COVID19 in each period (Information released at 6 pm on the day, referring to the previous day) (c) | | | | | | | | | | | | | | |
| | Growth of hospitalized cases | 6 | Rate of Variation of Inpatients (Clinical + ICU) in each period (Information released at 6 pm on the day, referring to the previous day) (c) | ✗ | ✓ | ✓ | ✓ | ✗ | = | 1.00 | 1.13 | Favorable | Favorable | Not Favorable | Not Favorable | Not Favorable | Not Favorable |
| | Variation of new cases | 7 | Number of cases reported by Influenza Syndrome (SG) in the last two epidemiological weeks of notification (d) | ✓ | = | = | = | = | = | 21,558 | 20,976 | Favorable | Favorable | Favorable | Not Favorable | Not Favorable | Not Favorable |
| OPINION FOR OPENING PHASE ACCORDING TO PRIMARY INDICATORS | | | | | | | | | | | | Missing Information | Missing Information | Missing Information | Missing Information | Missing Information | Missing Information |

# 6. TECHNOLOGY

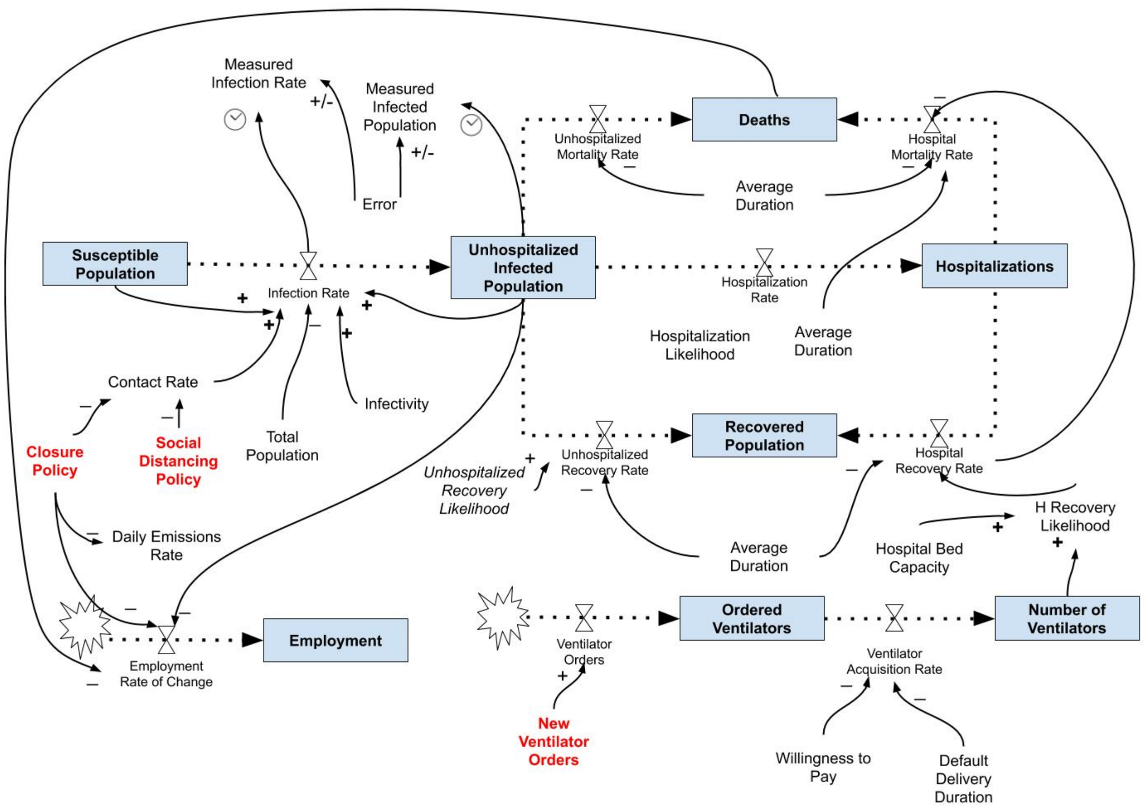
Various forms of sensing technology are relevant during a viral epidemic. While our team has remained primarily focused on satellite-based earth observation technology and in-situ environmental sensors, another key form of relevant sensing technology is coronavirus testing (both the technology of the individual tests and the social technology that is the regional testing regime).




Daily PCR tests conducted in the Metropolitana Region of Chile

# 2. PUBLIC HEALTH

The main focus of any pandemic response tool is public health. Rio de Janeiro, along with many other places, has been collecting and publishing coronavirus-related epidemiological data on a daily basis, including new identified infections, deaths, hospitilizations, etc [1]. This component is based on a Susceptible-Infected-Recovered (SIR) system dynamics model. SIR is a compartmental epidemiological model and one of the most commonly used variants, due to its relative simplicity and flexibility while system dynamics is a modeling approach commonly used in both 'pure' epidemiological contexts [2] and in broader public health policy contexts [3]. Below you can see a diagram depicting the initial layout of the Vida Public Health Model. In addition to the three traditional SIR components, it has two other health compartments: Hospitalizations and Deaths. These reflect some of the primary decision points and metrics of performance that policymakers are using. In most of our application contexts, population counts for each of these compartments is readily available on a daily or weekly basis.

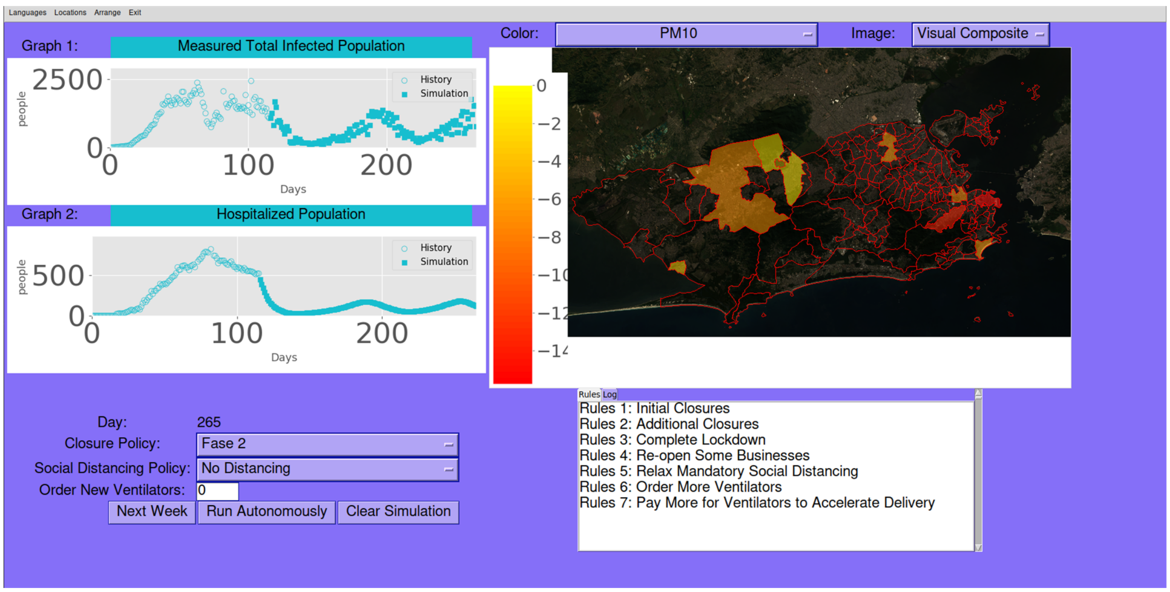



This public health model is being actively refined and validated in conjuction with Prof. Mohammad Jalali of Harvard Medical School.

# 7. APPLICATION CONTEXTS

In order to actually be useful as a decision support tool, the Vida model must have a user interface. This is being actively developed and a prototype can be seen below.

On the left, historical Public Health data (starting from early March, when the epidemic first reached the area) as well as simulated forecasts under certain conditional closure policy rules are shown. The map on the right shows geographic environmental data, specifically the mean anomaly for PM10 in the various neighborhoods of the city with the most consistent air quality data collection. In this case, the reference period was January 1, 2019 to March 1, 2020, while the observation period was March 1, 2020 to August 1, 2020. This air pollutant data is overlaid with satellite imagery, in this case a simple visual Landsat 8 surface reflectance composite.




To ensure accessibility, the user interface can present information in three different languages (English, Spanish, and Portuguese) with other languages planned to be added. This version is written in Python 3 and is able to be run on a standard personal laptop or desktop computer. The team is working with Blue Raster LLC to develop a web-based version as well. The code for this version is available at www.github.com/mitmedialab/Vida_Modeling, where it is frequently updated to include additional datasets, improving modeling, and addressed feedback from our international partners.

These international partners have been key to the ongoing success of this project. In particular they include the Instituto Pereira Passos of Rio de Janeiro; the Chilean Ministry of Science, Technology, Knowledge and Innovation; Doponegoro University in Indonesia; The Instituo Politécnico Nacional in Mexico; and the Angola National Space Program Management Office. For more information on our partnerships and collaborations with this institutions, see the Virtual Poster titled "Designing Decision Support Systems with Interdisciplinary, International Teams: A Case Study of the Environment, Vulnerability, Decision, Technology Model." (http://agu2020fallmeeting-agu.ipostersessions.com/Default.aspx?s=12-76-02-3F-B4-1D-EF-06-32-E7-77-14-F9-8C-D6-1A)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North Atlantic Ocean
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ASIA
AFRICA
SOUTH AMERICA
Chile
Rio De Janeiro, Brazil
South Atlantic Ocean
Angola
Indonesia
Indian Ocean
AUSTRALIA

# ABSTRACT

The COVID-19 pandemic has had a diverse range of both direct and indirect impacts on health (both physical and mental), the economy, and the environment. The relevant data sources used to inform pandemic-related decisions have been similarly diverse, though decision-makers have primarily relied upon data sets from non-satellite sources such as traditional public health data. As we move from initial crisis response to more long-term management, there is both an interest and a need for considering a wider diversity of data sources and impacts. It is difficult for any person to absorb and respond strategically to the broad sets of data that are relevant to the issues regarding COVID management. To address this, the authors propose a five part, integrated data visualization and modeling framework entitled the Vida Decision Support System. The goal of Vida is to create an accessible and openly available online platform that can be customized by the leadership team for a city or region and bring together knowledge from several areas of expertise. The five components of Vida, each of which serve to model a specific domain, include Public Health, Environment, Socio-economic Impacts, Public Policy, and Technology. This framework is currently being designed and evaluated with collaborators in Angola, Brazil, Chile, Indonesia, Mexico and the United States. The environmental data comes from sources such as in-situ sensors and both civil and commercial earth observation instruments (Landsat, VIIRS, Planet Labs' PlanetScope, etc.) to track factors such as water quality, forest extent and health, air quality, human mobility, and nighttime urban lighting. Similarly, socioeconomic data derives from both in-situ sources, such as local statistical agencies, and from satellite products, such as those hosted by NASA's Socioeconomic Data and Applications Center. The authors discuss the value provided by this framework to each of the collaborators, the process used to apply the framework to each local context, and future possibilities for Vida. Even though Vida was first developed and applied in response to COVID-19, it has applications in other public health contexts where policy, environment, and socio-economic impacts are closely tied.

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