Usefulness of Electoral Models for COVID-19 Vaccine Distribution

Héctor D. Hugo[1] · Jack Michel[2] · Christian Antón[3] · Washington R. Alemán[4] · Carlos Cueva[5] · Carlos Bort[6] · Francisco Andino[7] · Omoyeme Edaki[2] · Prakriti S. Shrestha[2] · Laura Rodó[2] · Angela Ishak[2] · Jonathan Quinonez[2] · Upasana Maskey[2] · Saleha Ozair[2] · Jinal Choudhari[2] · Sujan Poudel[2] · Vikash Jaiswal[2] · Zachary Au[2] · Usman Siddiqui[2] · Krunal Pandav[2] · Farah Chohan[2] · Manoel H. Cunha[8] · Marcelo Fioroni[8] · Luiz A. Franzese[8] · Javier Reaño[8] · Alfonso J. Rodriguez-Morales[9,10,11]

Abstract

Purpose of Review In response to the COVID-19 pandemic, there has been a remarkably accelerated development of vaccines worldwide. However, an effective distribution system is crucial for vaccination at a national level. Ecuador was one of the first Latin American countries to be most severely affected by the pandemic. It has been struggling to expand its vaccination drive and requires a strategy that provides an achievable vaccination rate and maintains its primary care services. This study aims to provide an efficient vaccination model to achieve herd immunity by utilizing the country's existing infrastructure (the centralized electoral system) for mass vaccination.

Recent Findings The national electoral data from 2017 and 2021 were used to create estimates for the proposed vaccination model. Two model variations, total personnel, needed, and the number of days needed to vaccinate 50%, 75%, and 100% of the population were considered. The numbers of vaccines needed, and vaccination sites were estimated based on the current number of registered voters and polling stations. The results from the proposed model show that 17,892,353 people can be vaccinated, at 40,093 polling stations, by 90,209 personnel if one vaccinator was available per polling station.

Summary Based on this model, even a conservative estimate shows that 12.56 days are needed to achieve herd immunity, and 16.74 days are needed to vaccinate the entire population of Ecuador. Additionally, we propose that this vaccination model can be used as a blueprint for any country to address similar catastrophes in the future.

Keywords COVID-19 · Mass vaccination · Electoral model · Epidemiology

---

This article is part of the Topical Collection on *COVID-19 in the Tropics: Impact and Solutions*

✉ Héctor D. Hugo
hector.hugou@ug.edu.ec

✉ Alfonso J. Rodriguez-Morales
alfonso.rodriguez@uam.edu.co

1 School of Jurisprudence, Social Sciences and Politics, University of Guayaquil, Cdla. Universitaria "Universidad de Guayaquil", Guayaquil 090510, Ecuador

2 Division of Research & Academic Affairs, Larkin Community Hospital, FL, Miami, USA

3 School of Mathematical and Physical Sciences, University of Guayaquil, Cdla. Universitaria "Universidad de Guayaquil", Guayaquil 090510, Ecuador

4 School of Health Sciences, Espiritu Santo University, Guayaquil, Ecuador

5 Ecuadorian Pharmaceutical Distributor (DIFARE), Guayaquil, Ecuador

6 Xplore.ai, Madrid, Spain

7 School of Medicine, Catholic University of Santiago de Guayaquil, Guayaquil, Ecuador

8 Paragon Decision Science, São Paulo, Brazil

9 Grupo de Investigación Biomedicina, Faculty of Medicine, Fundación Universitaria Autónoma de Las Américas, Belmonte, 660003 Pereira, Risaralda, Colombia

10 Universidad Científica del Sur, Lima, Peru

11 School of Medicine, Universidad Franz Tamayo, Cochabamba, Bolivia

Introduction

In the battle against COVID-19, 191 countries and territories have started their vaccination roll-out [1]. Up to July 25, 2021, 3.84 billion vaccine doses have been administered worldwide. There is a vast variation in the vaccination rates between countries ranging from 118 doses per 100 people in Israel to less than 0.1 doses per 100 people in countries that have just begun their vaccination campaigns, such as Mali, Namibia, and Brunei, with most countries in the developing world having alarmingly low rates of vaccination of less than 10% [2]. Ecuador was one of the worst affected countries in South America, with the highest per capita COVID-19 death toll in the region during the first wave of COVID 19 [3]. As of July 25, 2021, 17.74% of their population has been fully vaccinated, and 56.79% partially vaccinated against the virus [2]. It would require approximately 112 days to immunize 70% of the population with the current vaccination rate [4].

As nations race to attain herd immunity during the COVID-19 pandemic, the blueprint of how this will be achieved remains in question. Several proposals and strategies are written to guide this process in different countries exist. However, their ultimate effectiveness is uncertain. We propose an efficient and reliable plan to vaccinate all the citizens of Ecuador in remarkably fewer days than what the existing system could achieve [5, 6]. That is especially necessary with the emergence of new COVID-19 variants of concern [7]. This plan is based on a tested and proven effective electoral system that allows easy access to its electoral voting stations based on each citizen's residence [8]. This plan was already tested in Guayaquil, Ecuador and was a success [9].

Ecuador has a national election council that maintains voting records [8]. These records include names, ages, sex, and addresses. This information can estimate the number of vaccines distributed across various age groups and the required number of vaccine administrators needed to administer the doses. Although Ecuador's national vaccination plan is based solely on its national electoral system, it also recognizes the need for specific population groups to receive vaccines outside of their closest voting stations due to either underlying health conditions, remote location, or incarceration status. It is important to note that Ecuador had a very high voter turnout of 82.6% in the most recent election on April 11, 2021, which is the basis for the vaccination model [8]. Additionally, this plan accounts for children and foreigners in the country that are ineligible to vote.

The vaccination model assumes that records of all its people, regardless of their residence status, are contained in a vast electronic database. For the following vaccination model, the electronic databases of the following public institutions of Ecuador were synchronized: the National Electoral Council, the Civil Registry, the Ministry of Education, and the Ministry of Public Health. The latter body centralized the process and the data related to the individual records of each Ecuadorian regarding the type of the vaccine, the inoculation number, the dates, the lot of the vial used, the vaccination site, the vaccinator, and the professional in charge [10]. Additionally, the personal data of the person who received the vaccine, which made it possible to download a vaccination certificate, thus avoiding the consumption of human resources, time, and cost at the time of vaccination. Furthermore, each person can be identified and vaccinated according to their regional distribution to attain herd immunity. This plan can also be utilized to combat future pandemics or any similar catastrophes.

The Vaccination Model

Ecuador's national vaccination model has predetermined keys for success in its already established voting system. As soon as a child is born in Ecuador, they are automatically registered in the civil registry and the country's national electoral council [11]. This process is also similar for naturalized citizens and immigrants. As for foreigners, their information can be extracted using data from the consulates or embassies. The National Electoral Council (CNE) in Ecuador models data according to three entities: electoral precincts (buildings), voting receiving boards (JRV), and voters. Figure 1 shows the relationships between all entities.

Ecuador's population, including foreigners, will be divided into age groups: children < 16, teenagers 16–18, adults 18–65, and the elderly > 65 years. The priority will be given first to the elderly > 65 years of age, the frontline workers, and later adults between the ages of 18–65 years. Children will be vaccinated once the vaccine is approved for use in their age group. Ecuador's population, including foreigners, is 17,982,353, and 70% would need to be vaccinated using this model to reach herd immunity [12].

In the context of Ecuador's electoral system, Ecuadorians are assigned to go to a polling place (university or school) depending on their registered address when a voting day is announced. On the vaccination day, instead of ballots, vaccines will be delivered. Assigned dates and times for vaccines will be dependent upon the last digit of their government identification card (Table 1 and Fig. 2). Announcements will be made using a website, and for people without internet access, these will be made via television, radio, and text messaging. In addition, the Ecuadorian government will reach out through other means such as Los Equipos de Atención Integral de Salud (EAIS), a comprehensive health care team for rural and remote populations without access

**Entity Relationship Diagram of
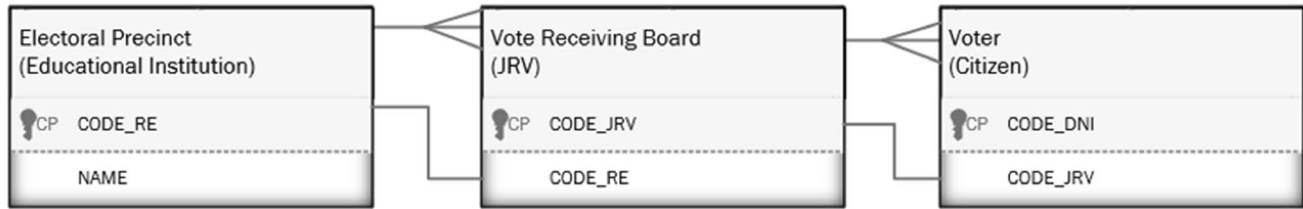the National Electoral System of
Ecuador (CNE)**

Fig. 1 The entity-relationship diagram of the CNE data model

to media. They are field brigades assigned by census sectors nationwide.

Background Mathematical Model

Ecuador's vaccination model is based upon a 2004 mathematical model by Brenes et al. [13] in which two equations describe the overall carrying capacity of a vaccination site. The two equations are described as below:

$$CCF = \frac{S}{Sp} * N_v \qquad (1)$$

$$NV = \frac{H_v}{T_v} \qquad (2)$$

where

CCF	physical load capacity
S	available surface
Sp	surface used per person
NV	number of times that a site can be visited
Hv	number of available visiting hours
Tv	time to visit a site

The above equations help determine the physical capacity of a vaccination site based upon available space, the number of visitors and operating hours, making it possible to estimate the maximum number of vaccinations that can be given in a day. These equations can also help estimate the number of healthcare workers needed to undergo a mass vaccination program. These equations are utilized in part of a larger model used to calculate the number of days needed to complete a mass vaccination program. Tables 2, 3, 4, and 5 show how the model can be utilized to predict a sample vaccination day.

Stages of the Ecuadorian Model

This model will incorporate three vaccination stages as described below:

1) Pre-vaccination—In the pre-vaccination stage, a "voter receiving board" (JRV) will consist of one or two individuals who will manage the patient's data and their verification. In addition, patients have an option through the interface to change their address. There is also another link for patients to upload proof of vaccination if they have been vaccinated abroad. In addition, any "at-risk" individuals requiring a hospital setting will be identified beforehand at this stage through the Ministry of Public Health's record, as it is tied to his or her government identification card (Fig. 3).

2) Vaccination—A "vaccinator," consisting of students (medical, nursing) and health care professionals, will administer the COVID-19 vaccine to a patient. To help with this stage, a course developed by the World Health

Table 1 A description of how appointment times are assigned. Based on the last number of the Ecuadorian identification card, a person is assigned an appointment time. Appointments last about 1 h. If a person does not have Ecuadorian identification, they would be allocated an appointment time under "other"

Last number of identification card	Start time -End time (hrs)
0	0800–0900
1	0900–1000
2	1000–1100
3	1100–1200
4	1200–1300
5	1300–1400
6	1400–1500
7	1500–1600
8	1600–1700
9	1700–1800
"Other"	1800–2000

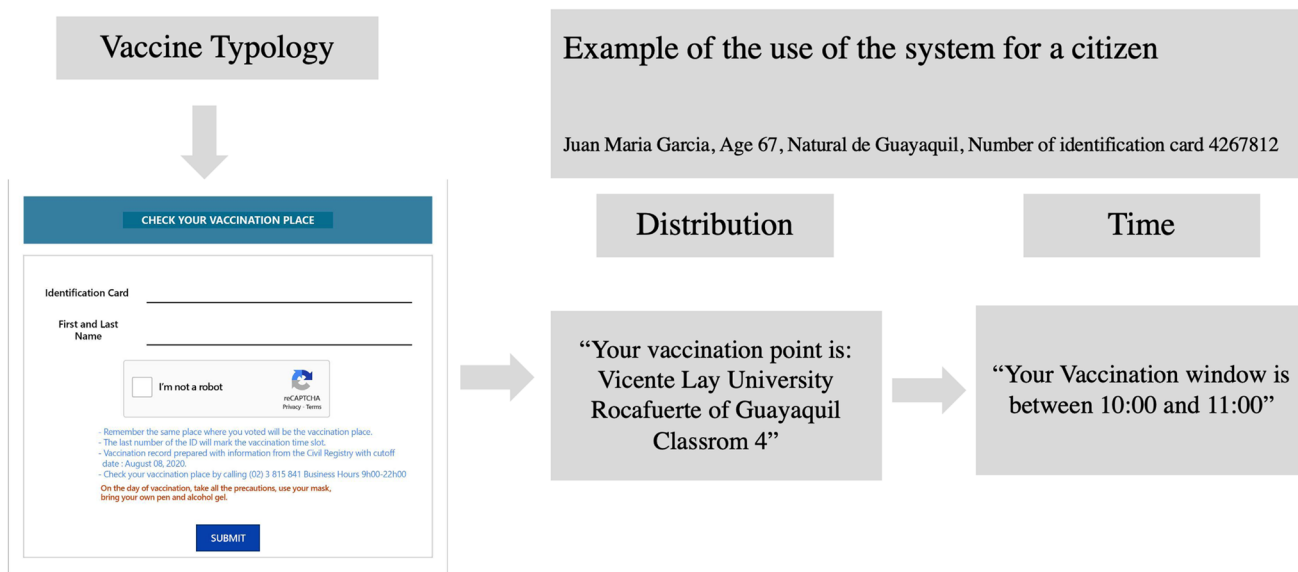# Example of assigning place and time of a citizen

Fig. 2 A summary of the assignment process. Patient information is provided in a secure portal. When specific information is identified, a patient receives a notification about the location and time

Organization (WHO) and UNICEF can train healthcare providers. These courses include six modules with video tutorials, questionnaires, work aids, interactive exercises, and downloadable presentations. They are available in different languages and are a valuable resource for frontline healthcare workers for this project in different countries [14].

3) Post-vaccination—In this stage, the patient will be observed by a medical team for 15–20 min. Second doses of the COVID-19 vaccine will be scheduled soon after, at the same location to eliminate any confusion. In addition, a vaccination card will be provided to every

person in the form of a digital certificate with a Quick Response (QR) code via a mobile application that can be used for traveling and returning to the workplace if needed (Fig. 4).

This model would also follow strict protocols to reduce transmission of COVID-19. These include the social distancing, masks, and use of open space at vaccination sites. In a previous paper, we described a collaboration between the city council, volunteers, and different professionals in establishing urban open spaces in the University of Guayaquil

Table 2 Voter data from 2017 and input variables to determine the estimated number of JRV (voter receiving boards) per registered voters

CNE Model 2017	Registered voters
Electors 16–18 years	676,147
Electors 18–65 years	10,350,637
Electors 65 +	1,411,622
Non-registered voters	5,072,440
Total electors	12,438,406
Electoral locations	3452
Number of JRV	40,093
Average of registered voters per JRV	310.24
Number of JRV X average of registered voters per JRV	12,428,830 (99.92%)

CNE, National Electoral System; *JRV*, voter receiving board

Table 3 Current population data as well as the number of vaccine sites. The Brenes model equations can be utilized and modified to determine how many vaccination sites are needed

Vaccination Model 2021	Registered voters + foreigners
Group O to 16 years	5,182,953
Group 16–18 years	690,878
Group 18–65 years	10,576,145
Group 65 +	1,442,377
Total of population requiring vaccination	17,892,353
Vaccination sites	4966
Number of vaccination points	57,673
Average of population requiring vaccination per PV	446.27

PV, vaccination point

Table 4 The 2017 National Electoral Council Model and the 2021 Vaccination model show the difference in population and vaccination point numbers

CNE Model (2017) versus Vaccination Model (2021)	
Vaccination sites (2021)	4966
Electoral locations (2017)	3452
Difference between electoral locations and vaccination sites	1514
Number of vaccination points (2021)	57,673
Number of JRV (2017)	40,093
Difference between JRV and PV	17,580
Average of population requiring vaccination per PV (2021)	446.27
Average of registered voters per JRV (2017)	310.24
Difference between registered population per PV and CNE registered voters	136.03

PV, vaccination point; *JRV*, voter receiving board; *CNE*, National Electoral System

Table 5 Estimates of required time and personnel needed for the Vaccination Model using the Brenes model

Voting time (min)	600
Average theoretical time per person (min)	1.94
No of hours per day	10
Approx. waiting time for pre-vaccination (min)	7.5
Approx. waiting time for post-vaccination (min)	2.5
Inoculation time (min)	5
Average time of vaccination process per person (min)	15
No. of hours × working day	10
No. of people in post-vaccine	4
No. pf people in pre-vaccine	4
No. pf digitator (pre-vaccine)	1
No. of controller (post-vaccine)	1
Total time allocated to the vaccination process (min)	600
Average of population requiring vaccination per PV	446.27
Average time of vaccination process per person (min)	15
Total vaccination time (min)	6,694
Total duration in times of the process	11.16*
Vaccinators needed	80,186*
Required digitators	40,093
Controllers required	40,093
Total staffs required for vaccination	160,372

PV, vaccination point

[15]. Similar open spaces can be established across Ecuador to serve as vaccination sites.

The voting stations will be converted into vaccinations sites considering the most basic health standards and protocols. These include the following:

- Wide and ventilated places to avoid aerosols
- Controlled use of masks and hand hygiene when entering the premises

- Bathrooms in suitable condition
- Pre- and post-vaccination rooms with separate chairs respecting the rules of social distancing
- Air-conditioned rooms and personal cold containers for the collection and handling of vaccines, to guarantee respecting the standard cold chain protocol
- Triage room for prior control of vital signs
- Protocol to follow in case of reactions or side effects
- Custody and transportation of goods and supplies by the armed forces
- Information communications technology (ICT) logistics

Simulation Through Arena Software

Discrete event simulation is one of the most precise tools available in operations research, especially when studying complex systems. However, many interactions between its elements and process time are subject to randomness. For example, this was the case in the Ecuador vaccination system studied. Nevertheless, simulation has been used to fight the pandemic in many ways, by studying ways to reduce and even eliminate the pandemic's impact on the population, like the present study, and deal with its consequences [16].

The model was constructed in the software Arena®, following the decision flow shown in Fig. 3. The input data used to experiment with the system is shown in Tables 2, 3, and 4, adapted to reproduce the number of people needed to vaccinate. Also, process times of pre-vaccination, inoculation and post-vaccination stages were extracted from Table 5.
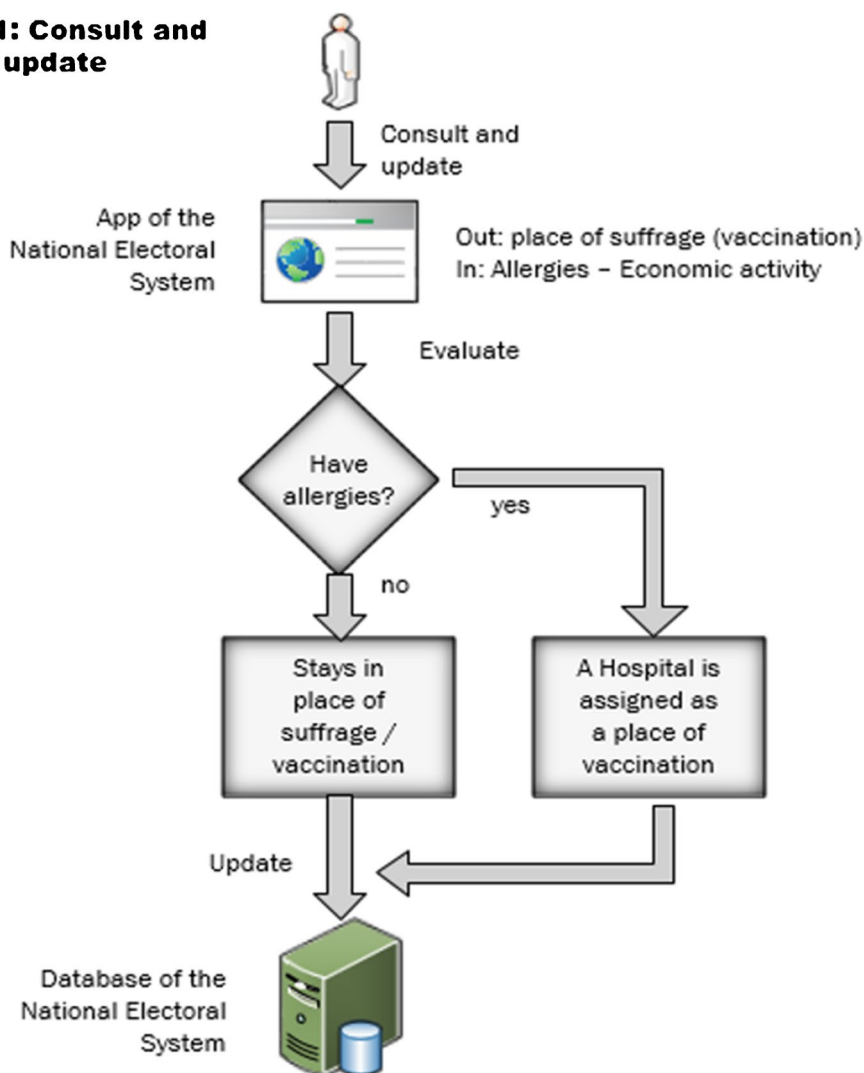
The study assumes that all vaccination sites follow the same process flow, and have similar capacity and behavior, reproducing the concept of the voting system. A standard layout of a school was used to create the animation interface of the model, shown in Fig. 5 and Video S1, where the population can be seen circulating throughout the system and interacting with its resources to vaccinate, eventually accumulating in queues. The precision of the model was determined using the technique proposed by Freitas [17], achieving 95% of confidence with 80 replications. That was the number used to run the experiments. The simulation proves that it is possible to vaccinate more than 3000 people in 12 h if 25 JRVs are available, and it takes 5 min to vaccinate one person (Video S1).

Brenes Model

The results from the proposed model show that 17,892,353 people can be vaccinated, at 40,093 polling stations, by 90,209 personnel (Table 6). Based on this model, even a conservative estimate shows that 12.56 days are needed to

Fig. 3 An algorithm to determine if specific patient populations require the hospital setting

STEP 1: Consult and update

Consult and update

App of the National Electoral System

Out: place of suffrage (vaccination)
In: Allergies – Economic activity

Evaluate

Have allergies?

yes

no

Stays in place of suffrage / vaccination

A Hospital is assigned as a place of vaccination

Update

Database of the National Electoral System

achieve herd immunity, and 16.74 days are needed to vaccinate the entire population of Ecuador if there is one vaccinator available per voting receiving board (Table 7). On the other hand, if two vaccinators are available per voting receiving board, then 8.37 days are needed to achieve herd immunity, and 11.716 days are needed to vaccinate the entire population (Table 8). That, however, would require 130,302 personnel (Table 9).

Discussion

Using an established electoral system for mass vaccinations offers numerous advantages. To begin, there will be no need to build new infrastructure to vaccinate the population. Existing polling sites will be used, and this cuts down costs substantially. Ecuador had a voter turnout of 81% in their recent election in 2021, making most of the population already familiar with the location of the polling sites [18].

Furthermore, their electoral system maintains an extensive repository of all eligible voters as, under the law, a person is fined if they do not participate in the elections [19]. As a result, an accurate estimate of the number of vaccines needed per site can be made. Secondly, as the ministry of public health keeps health records of all its citizens, vulnerable citizens would be directly sent to facilities that can take care of them.

Additionally, addresses of all citizens are stored in the civil registry, so when appointed, the site would be in close vicinity. Thus, geographical and data science can aid epidemiologists in identifying cities or provinces with high numbers of cases or fatalities and promptly target these areas with vaccination as successfully attempted previously in the city of Guayaquil in Ecuador [20]. Guayaquil was the first city to be overwhelmingly affected by the pandemic and following the strategy of "making an invisible enemy visible," geographical and data science helped Guayaquil to recover quickly by allowing the municipality and private companies
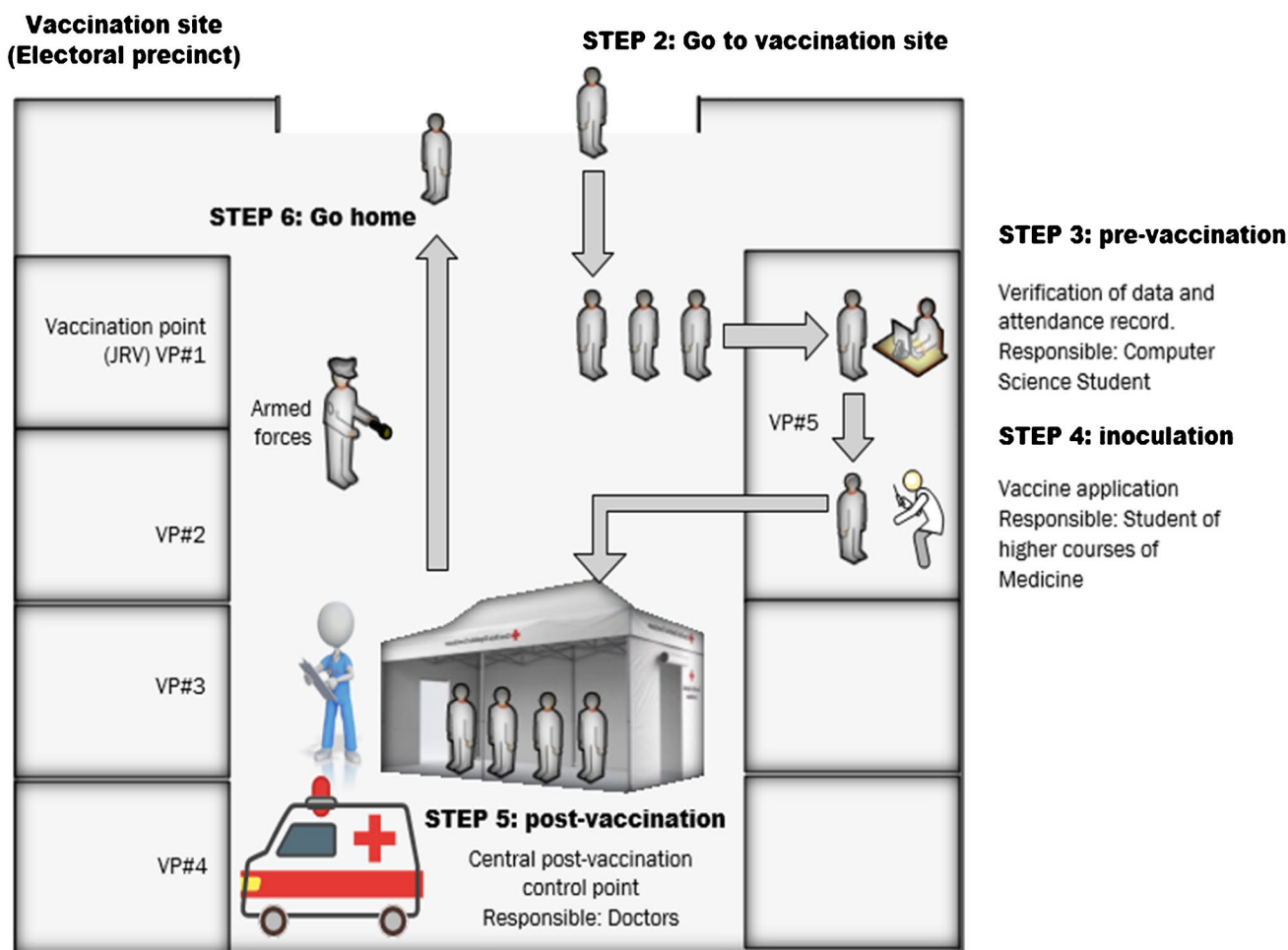
Fig. 4 A summary of the vaccination and post-vaccination stages. When a patient arrives at an assigned vaccination site, a "verification team" serves to verify the patient's information. The patient then receives a vaccine and immediately undergoes a 15–20-min observation. When no immediate reactions are observed, the patient then schedules a second appointment and is allowed to go home

to direct their efforts to the areas with the highest number of cases [20].

Moreover, vaccinating province by province will allow businesses to re-open once a province reaches herd immunity, preventing any mass lockdown and its detrimental effects on the country's economy as witnessed in other countries [21]. Thirdly, this plan can serve as an incentive for healthcare students to gain experience during public health crises. Medical schools can also use it as a part of their training or mandatory community service in countries that require it [22]. Using healthcare students also ensures that the healthcare system does not get overwhelmed. The electoral system also rewards citizens who volunteer with compensation or paid leave from their work. A similar strategy can be adopted in this context. This ensures maximum participation of the non-medical workforce, which further decreases the country's healthcare system burden.

Finally, it ensures equitable vaccine distribution to the whole population without any cities or local hospitals competing for vaccine allocation. It also ensures that minority groups have adequate amounts of vaccines based on their geographical distribution. That is via the JRV, which will allocate vaccines based on population numbers rather than allow medical institutions to compete for vaccine supplies. If an inadequate vaccine supply exists, then JRVs can merge. This system also addresses social determinants of healthcare that can place minority groups at a disadvantage. Although the infrastructure of the electoral voting system varies from country to country, this model is flexible enough to adapt and accommodate each system, ensuring effective and rapid achievement of reaching herd immunity in a short period.

The application of this model is significantly valuable for the global platform and may assist different WHO regions to achieve the vaccination goal in the short-designated time. This model can be adapted to any county where electoral-based databases are available for vote casting and citizens have been well versed with the process and transforming the available polling stations into the vaccination sites with
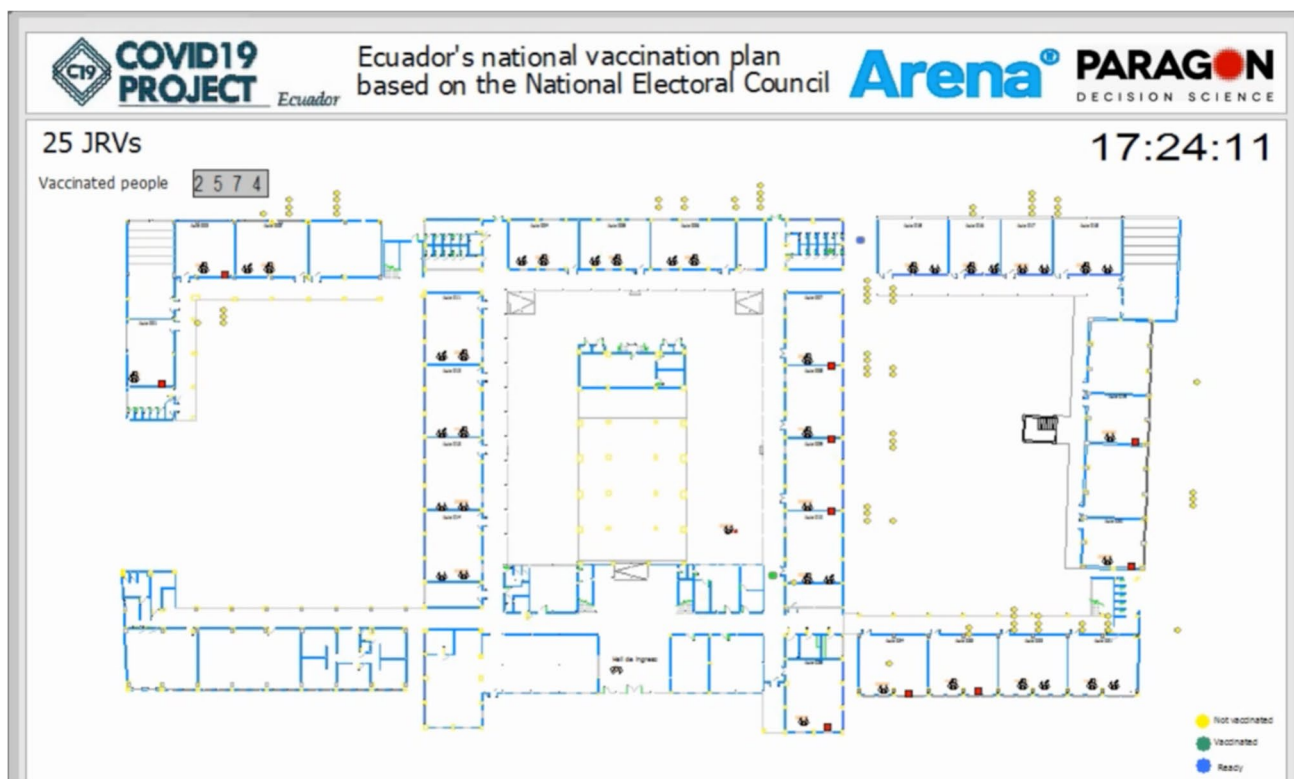
Fig. 5 Animated interface of the simulation model made in Arena software

Table 6 Number of necessary personnel if there is only one vaccinator available per voting receiving board

Requirement variables	Quantity
Necessary vaccinators	40,093
Pre-vaccine personnel	40,093
Post-vaccine personnel	10,023
Total vaccination personnel	90,209

country-specific protocol in place. For example, the largest country like India has adapted similar concepts to vaccinate their citizens of Delhi, a major metropolitan city, by launching a door-to-door survey at their polling booths [23]. They assigned a polling booth level officer who will knock on every door of their 280 wards (electoral site) to vaccinate their citizens above 45 years within four weeks given the sufficient supply [23]. Similarly, the South African government has adopted and implemented a similar strategy to vaccinate the people in the polling stations soon after they were finished with the voting process for the election held

Table 7 Number of days necessary to vaccinate 50%, 75%, and 100% of the population if there is only one vaccinator available per voting receiving board

Group (variables)	Quantity	Days 100% of population covered	Days 75% of population covered	Days 50% of population covered
Children	5,182,953	4.85	3.64	2.43
Teens	690,878	0.65	0.49	0.33
Seniors	1,442,377	1.35	1.01	0.68
Commerce	1,938,607	1.81	1.36	0.91
Services	5,926,872	5.54	4.16	2.77
Manufacturers	1,352,689	1.27	0.95	0.64
Mines and quarries	131,144	0.12	0.09	0.06
Agriculture and cattle raisers	812,248	0.76	0.57	0.38
Construction workers	414,585	0.39	0.29	0.20
Total	17,892,353	16.74	12.56	8.37

Table 8 Number of necessary personnel if there are two vaccinators available per voting receiving board

Staff variables	Quantity
Necessary vaccinators	80,186
Pre-vaccine personnel	40,093
Post-vaccine personnel	10,023
Total vaccination personnel	130,302

on November 1, 2021 [24]. Around 1000 vaccination sites were set up around some of the 23,000 polling stations in South Africa [24]. In Botukatu City in the southeastern part of Brazil, mass vaccination campaigns were implemented to deliver AstraZeneca/Oxford vaccine, and 45 traditional voting locations were transformed into vaccination posts. In the first 2 h of starting, they vaccinated more than 5000 people of the city [25]. Hence, the electoral model for vaccination concept has been adapted in three WHO regions countries, namely Regions of the Americas (AMR, Ecuador, and Brazil), the African Regions (AFR, South Africa), and the southeast Asian region (SEAR, India) and can be successfully adapted in the rest of WHO regions by converting the polling stations to vaccination sites.

Limitations

Mass vaccination with this proposed model requires staff members to be deployed at vaccine sites as volunteers. Countries with a limited number of medical or nursing students and staff might need additional community members to be trained as volunteers. This might require financial compensation. Countries with a limited fiscal capacity might not overcome this limitation without modifications to the existing model. Another major limitation is the political will of a country to attempt using this mass vaccination model.

Vaccine hesitancy is another limitation that could negatively impact this model. Finally, some countries may lack a physical voting system or infrastructure to utilize as vaccination sites close to the residence of the electorate. However, in such cases, countries can continuously adapt and use nearby infrastructures such as supermarkets, stadiums, coliseums, parks, pharmacies, or private companies as vaccination sites.

A final limitation, especially for low-to-middle income (LMIC) countries, is the available vaccine inventory each country possesses. The COVAX initiative by the WHO, CEPI, Gavi, and UNICEF was started to overcome these limitations by accelerating the production and distribution of COVID-19 vaccinations in LMIC countries such as Ecuador [26]. Despite this initiative, there still appears to be a significant imbalance in the global distribution of vaccinations. In Ecuador's case, this was overcome by negotiating vaccination purchases for the lowest possible prices directly from vaccine manufactures [27].

Conclusions

The fight against novel coronavirus is a time-sensitive matter. Planning and implementing a mass vaccination strategy will aid a country in current and future pandemic situations if existing systems are utilized. As in the case of Ecuador, a country's electoral system, which is already running and defined, can facilitate the mass vaccination process. Ecuador, for example, can quickly categorize and assign vaccination appointments based upon their government identification card system. Through the above approach, achieving a herd immunity of 70% will be quick and effective if implemented correctly. Thus, utilizing and modifying the existing electoral structure that almost every country has may be necessary to combat current pandemic situations and future pandemics or even epidemics. We propose that this vaccination model can be used as

Table 9 Number of days necessary to vaccinate 50%, 75%, and 100% of the population if there are two vaccinators available per voting receiving board

Group (variables)	Quantity	Days 100% of population covered	Days 75% of population covered	Days 50% of population covered
Children	5,182,953	3.23	2.42	1.62
Teens	690,878	0.43	0.32	0.22
Seniors	1,442,377	0.90	0.68	0.45
Commerce	1,938,607	1.21	0.91	0.61
Services	5,926,872	3.70	2.78	1.85
Manufacturers	1,352,689	0.84	0.63	0.42
Mines and quarries	131,144	0.08	0.06	0.04
Agriculture and cattle raisers	812,248	0.51	0.38	0.26
Construction workers	414,585	0.26	0.20	0.13
TOTAL	17,892,353	11.16	8.37	5.58

a blueprint for any country to address similar catastrophes in the future. In addition to vaccination, a healthy lifestyle must be maintained. This could be done using projects like the Delta project to transform public spaces into open areas that the public can use to improve the population's quality of life [15].

Declarations

References

1. World Health Organization. WHO Coronavirus (COVID-19) dashboard [Internet]. 2021 [cited 2021 Jun 4]. Available from: https://covid19.who.int.
2. Mathieu E, Ritchie H, Ortiz-Ospina E, Roser M, Hasell J, Appel C, et al. A global database of COVID-19 vaccinations. Nat Hum Behav. 2021;5:947–53.
3. Guillaume L. How Ecuador Descended into COVID-19 Chaos [Internet]. Center for Economic and Policy Research. 2020 [cited 2021 Jun 4]. Available from: https://cepr.net/how-did-ecuador-spiral-into-its-covid-19-nightmare/.
4. Peter G. Time to herd: tracking Covid-19 vaccination rates around the world [Internet]. TimeToHerd. [cited 2021 Jun 4]. Available from: https://timetoherd.com.
5. Zuñiga C. Vacunar a la población de Ecuador en un mes o máximo dos es posible con plan ideado por gremio de expertos; está a disposición de las autoridades [Internet]. El Universo. 2021 [cited 2021 Jun 18]. Available from: https://www.eluniverso.com/noticias/ecuador/vacunar-a-la-poblacion-de-ecuador-en-un-mes-o-maximo-dos-es-posible-con-plan-ideado-por-gremio-de-expertos-esta-a-disposicion-de-las-autoridades-nota/.
6. Especialistas dicen cómo vacunar al 70% de ecuatorianos en dos meses (y otras noticias en un resumen para iniciar la jornada) [Internet]. El Universo. 2021 [cited 2021 Jun 18]. Available from: https://www.eluniverso.com/noticias/ecuador/especialistas-dicen-como-vacunar-al-70-de-ecuatorianos-en-dos-meses-y-otras-noticias-en-un-resumen-para-iniciar-la-jornada-nota/.
7. van Oosterhout C, Hall N, Ly H, Tyler KM. COVID-19 evolution during the pandemic – implications of new SARS-CoV-2 variants on disease control and public health policies. Virulence. 2021;12:507–8.
8. Harrison C. Explainer: Ecuador's 2021 presidential elections [Internet]. AS/COA. [cited 2021 Jun 3]. Available from: https://www.as-coa.org/articles/explainer-ecuadors-2021-presidential-elections.
9. Paucar E. Vacunómetro, herramienta para seguir el pulso a la inmunización contra el covid-19 [Internet]. El Comercio. 2021 [cited 2021 Jun 18]. Available from: https://www.elcomercio.com/tendencias/sociedad/vacunometro-herramienta-pulso-inmunizacion-covid19.html.
10. Pinchao J. Así puede descargar el certificado de vacunación contra el covid-19 en Ecuador [Internet]. El Comercio. 2021 [cited 2022 Aug 25]. Available from: https://www.elcomercio.com/tendencias/sociedad/pasos-descargar-certificado-vacunacion-covid19-ecuador.html.
11. Trámites ciudadanos: paso a paso para realizar una inscripción de nacimiento en Ecuador [Internet]. El Universo. 2021 [cited 2022 Mar 2]. Available from: https://www.eluniverso.com/noticias/ecuador/tramites-ciudadanos-paso-a-paso-para-realizar-una-inscripcion-de-nacimiento-en-ecuador-nota/.
12. Inicio [Internet]. [cited 2022 Mar 2]. Available from: https://www.ecuadorencifras.gob.ec/estadisticas/.
13. Brenes O, Castro K, Jiménez V, Mora A, Mejía I. Determinación de La Capacidad de Carga Turística Del Parque Internacional La Amistad. San Jose, Costa Rica; 2007.
14. World Health Organization. Capacitación para personal sanitario sobre vacunación contra la COVID-19 [Internet]. OpenWHO. [cited 2022 Mar 2]. Available from: https://openwho.org/courses/covid-19-vacunacion-personalsanitarios-es.
15. Hugo H, Espinoza F, Morales I, Ortiz E, Pérez S, Salcedo G. Delta project: towards a sustainable campus. Sustainability. 2018;10:3695. https://doi.org/10.3390/su10103695
16. de Brito Jr I, Cunha MHC, Tozi LA, Franzese LA, Frazão ML da S, Bressane A. Managing funerary systems in the pandemic: lessons learned and an application of a scenario simulation in São Paulo City, Brazil. JHLSCM. 2021;11:481–92.
17. Freitas Filho PJ de. Introdução à Modelagem e Simulação de Sistemas. Florianópolis, SC, Brazil: Visual Books; 2008.
18. IDEA. Ecuador [Internet]. International institute for democracy and electoral assistance (International IDEA). [cited 2021 Jun 3]. Available from: https://www.idea.int/data-tools/country-view/98/40.

19. IDEA. Compulsory voting [Internet]. International Institute for Democracy and Electoral Assistance (International IDEA). [cited 2021 Jun 3]. Available from: https://www.idea.int/data-tools/data/voter-turnout/compulsory-voting.

20. Dube R, José de C. Ecuador city beat one of world's worst outbreaks of Covid-19 [Internet]. The Wall Street Journal. 2020 [cited 2022 Jun 3]. Available from: https://www.wsj.com/articles/ecuador-city-beat-one-of-worlds-worst-outbreaks-of-covid-19-11593532974.

21. Verschuur J, Koks EE, Hall JW. Global economic impacts of COVID-19 lockdown measures stand out in high-frequency shipping data. PLoS ONE 16(4):e0248818. https://doi.org/10.1371/journal.pone.0248818

22. Frehywot S, Mullan F, Payne PW, Ross H. Compulsory service programmes for recruiting health workers in remote and rural areas: do they work? Bull World Health Organ. 2010;88:364–70.

23. Dey S. Arvind Kejriwal announces voting booth-level vaccinations, home survey [Internet]. NDTV.com. [cited 2022 Mar 2]. Available from: https://www.ndtv.com/india-news/arvind-kejriwal-announces-plan-to-enlist-poll-booth-level-officers-to-vaccinate-delhi-2458025.

24. Xinhua. South Africa to vaccinate people near voting stations [Internet]. CGTN Africa. [cited 2022 Mar 2]. Available from: https://africa.cgtn.com/2021/10/30/south-africa-to-vaccinate-people-near-voting-stations/.

25. Marina P. Study measures COVID-19 vaccine's effectiveness against variants [Internet]. Fiocruz. [cited 2022 Mar 2]. Available from: https://portal.fiocruz.br/en/news/study-measures-covid-19-vaccines-effectiveness-against-variants.

26. World Health Organization. COVAX Working for global equitable access to COVID-19 vaccines [Internet]. World Health Organization. 2021 [cited 2022 Aug 25]. Available from: https://www.who.int/initiatives/act-accelerator/covax.

27. Reuters. Ecuador signs agreement with Sinovac for 2 million COVID-19 vaccine: minister [Internet]. Reuters. 2021 [cited 2022 Aug 25]. Available from: https://www.reuters.com/article/health-coronavirus-vaccines-ecuador-idUSL1N2KV3J6.

Springer