# MANAGEMENT EPIDEMICS USING HIGH COMPLEXITY MATHEMATICAL MODELING

## PART II - ANNEX A

## SEIMR/R-S
## General Epidemic Simulation Model
## Multi-Infected States - Multi Socio-Demographics Segments - Multi-Region Mobility

## PARAMETERS MODEL
## Case: Bogotá

**Working Paper Version 1.5**

Actual version: http://www.doanalytics.net/Documents/DW-2A-ITM-SEIMR-R-S-Epidemic-Model-Cases.pdf


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"POR MI PATRIA Y POR MI BIEN"

**Bogotá, December 2020**

# 1. CASE: SEI3RD BOGOTA EPIDEMIC MODEL

To validate the **SEIMR/R-S** was selected the **SEI3RD** model used by the Mayor of Bogotá City (**MBC** Colombia). The version used is reported in Mejía Becerra (2020).

## 1.1. BIOLOGICAL PARAMETERS

The **SEI3RD** (used by MBC) is a particular case of **SEIMR/R-S**, so we should analyze how to enhance equivalent runs in such a way that you can compare the results.

Considering that the parameters used **SEI3RD** do not depend on the age and that they do not are the result of an explicit calculus process it is included an equivalent read parameters process to simulate the case of Bogotá with the **SEIMR/R-S** model. Next table shows the relationship between the two set of parameters. It includes parameters to management simple quarantine control policies ($\xi^Q_{st}$ and $c^Q_{st}$).

| BIOLOGICAL PARAMETERS – SEI3RD & SEIMR/R-S MODELS | | | |
|---|---|---|---|
| **SEI3RD Parameter** | **SEIMR/R-S Parameter** | **Description** | **Measure Unit** |
| $\mu^N$ | $\mu^N$ | Natural mortality rate | fpo/day |
| $\kappa$ | $\kappa$ | The latency period of the virus before developing | day |
| $\mu$ | $\mu_{ag}$ | Epidemic mortality rate | fpo/day |
| $\omega$ | $\omega_{rg,ss}$ | Probability of that a person may be contagion | prob |
| $\delta_{st}$ | $\delta_{ag,st}$ | Probability of $I_0$, $I_1$, $I_2$, $I_3$, … recovering without worsening the clinical condition. | prob |
| $\pi_{st}$ | $\pi_{ag,st}$ | Time a patient in $I_0$, $I_1$, $I_2$, $I_3$, … recovers | day |
| $\eta_{st}$ | $\eta_{ag,st}$ | Time a patient in $I_0$, $I_1$, $I_2$, $I_3$, … to next infected state | day |
| $\zeta_{st}$ | $\zeta$ | Total contact free rate in $I_1$, $I_2$, $I_3$, … | 1/day |
| $\zeta^Q_{st}$ | $\zeta^Q$ | Total contact confined rate in $I_1$, $I_2$, $I_3$, … | 1/day |
| $c_{st}$ | $c_{ag,st}$ | Probability of contagion in free state $I_1$, $I_2$, $I_3$, … | prob |
| $c^Q_{st}$ | $c^Q_{ag,st}$ | Probability of contagion in confined state $I_1$, $I_2$, $I_3$, … | Prob |
| $\beta_{st}$ | $\beta$ | Transmissibility rate of an individual in state st | |
| $\beta^Q_{st}$ | | Transmissibility rate of an individual in state st on quarantine | |
| $\beta\delta_{t,st}$ | | Dynamic rate of transmissibility calculated as $\beta\delta_{t,st} = (1 - \theta_{t,st}) \times \beta^Q_{st} + \theta_{t,st} \times \beta_{st}$ | |
| $\theta_{t,st}$ | | Epidemic control parameter (proportion of the st-state that circulates freely) | |

Because the variability of the **SEI3RD** parameters is simpler than that of the **SEIMR/R-S** parameters it is possible to replace the **SEIMR/R-S** parameters with the **SEI3RD** and have an equivalent model, but less explanatory of the details that differentiate sociodemographic segments and regions.

## 1.2. EPIDEMIC CONTROL POLICIES

These confinement policies are based on determining the fraction of the population to be confined to each region-segment during each period of the planning horizon. The impact on the epidemic is measured by altering the epidemiological parameters that are calculated based on an analysis that refers to the work of Mejia Becerra et. al (2020).

In the analysis presented by the MBC, two scenarios are established:

i) The population has no restrictions (the individual can move freely), and
ii) The quarantined population (individuals stay in their homes), to achieve this is modeled the dynamic changes in the rate of transmissibility $\beta\delta_{t,st}$.

The MBC calculates $\beta\delta_{st,t}$ as

$$\beta\delta_{st,t} = (1 - \theta_{t,st}) \times \beta^Q_{st} + \theta_{t,st} \times \beta_{st} , \quad \forall st = I0, I1$$

$\beta\delta_{st,t}$ is calculated for moderate asymptomatic and symptomatic individuals. $\beta_{st}$ and $\beta^{Q}_{st}$ are transmissibility rates for an asymptomatic or moderate individual who circulates freely within the population and an individual who stays in their home, respectively.

$\theta_{t,st}$ is the epidemic control variable that represents the population fraction of the st-state that circulates freely in the population ($0 \leq \theta_{t,st} \leq 1$). $\beta_{st}$ and $\beta^{Q}_{st}$ are the transmissibility rates for an individual who circulates freely within the population and an individual who stays in their home, respectively. Q superscript indicates the rate associated to a confined state. In simulation models $\theta_{t,st}$ is pre-defined by the user, a parameter.

$\beta_{st}$ and $\beta^{Q}_{st}$ can be expressed as the total contact rate (the total number of contacts susceptible by an effective or non-effective infective individual, per unit of time), multiplied by the probability of infection, given the contact between an infectious and susceptible individual. The formulas for the transmissibility rates are

$$\beta_{st} = - \zeta_{st} \log(1 - c_{st}) \approx \zeta_{st} \times c_{st}$$

$$\beta^{Q}_{st} = - \zeta^{Q}_{st} \log(1 - c^{Q}_{st}) \approx \zeta^{Q}_{st} \times c^{Q}_{st}$$

where $\zeta_{st}$ and $\zeta^{Q}_{st}$ are the average daily effective contact rate for an individual in state $I_{st}$ (i.e. how many contacts a state person has in one day) and $c_{st}$ and $c^{Q}_{st}$ is the contagion probability given effective contact with an individual in the susceptible group.

Alternatively, $\beta\delta_{st,t}$ may be calculated as

$$\beta\delta_{st,t} = \alpha_{t,st} \times \beta^{Q}_{st} + (1 - \alpha_{t,st}) \times \beta_{st} , \ \forall st = I0, I1$$

where $\alpha_{t,st} = 1 - \theta_{t,st}$ represents the fraction of people confined

In OPTEX notation the last equation is represented as

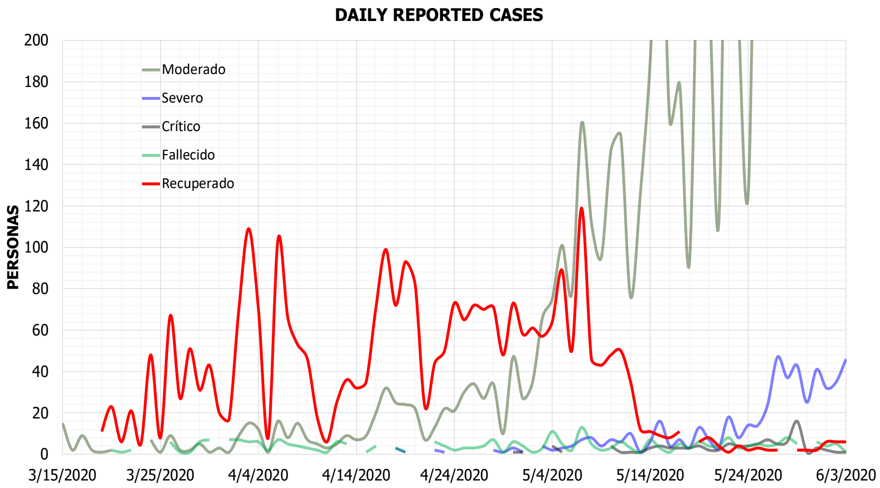
$$BETEF_{t,st} = ALFA_{t,st} \times BETAQ_{st} + BETAB_{st} \times (1 - ALFA_{t,st})$$

where

| | |
|---|---|
| **$BETEF_{t,st}$** | Effective transmissibility rate in st-state during t-period |
| **ALFAt,st** | Fraction of population in quarantine during t-period |
| **$BETAB_{st}$** | Free Transmissibility rate in st-state |
| **$BETAQ_{st}$** | Quarantine transmissibility in st-state |

## 1.3. HISTORICAL BEHAVIOR OF COVID 19 IN BOGOTA

The first COVID-19 case reported by the Ministry of Health in Colombia was filed on 6 March 2020 and corresponded to a 19-year-old woman in Bogota arriving from Milan, Italy. In Colombia, it has decreed total quarantine in Colombia from 25 March 2020. By the same day, 470 cases had been reported, of which four patients had died (lethality 0.8%) and eight patients had recovered (recovery rate 1.7%). Regarding the source of contagion, a total of 266 (56.6%) cases were imported, 163 (34.7%) related cases and 41 (8.7%) cases were under study. Bogota was 36% of the cases. As of 31 May 2020, 34.1% of the reported cases in Colombia of COVID-19 were in Bogota, with a total of 9,989 confirmed cases of which, 48.2% are women, and the highest concentration of cases according to age, is between 20 and 39 years with a percentage weight of 42.7%. The following figure presents the historical series of the cases reported in the city of Bogotá until May 31, 2020.




Source:

- Instituto Nacional de Salud de Colombia [Internet] Coronavirus (CO-VID-19) en Colombia. 2020. Citado 1 de junio de 2020. Disponible en: Disponible en: https://bit.ly/2UNnOtl
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## 1.4. DATA USED BY MAYOR OF BOGOTA CITY

The experiments taken as a reference was made by the Mayor of City of Bogotá (**MBC**) correspond to those reported on April 4, 2020 and have as a start date of March 15, 2020, to consider that there is a period between the start date of symptomatic and the date of diagnosis, on this date it was recorded: an individual hospitalized and 115 more symptomatic moderate moderates, in addition, $R_0$=2.6 was taken, and the MBC assumed, by expert discretion, the average latency time of one day ($\kappa$=1). The population of Bogota used was 7'413,000 inhabitants (corresponds to the estimated population for Bogota for 2018, according to Population Projections 2018-2023, DANE). MBC modeling assumes that the entire population is homogeneous, i.e., no differentiation of the location, age, economic stratum, and activity of individuals is made.

However, following the document "Análisis Demográfico y Proyecciones Poblacionales de Bogotá" (published by MBC in March 2018), the population of Bogotá amounts to the sum 8'380,801 inhabitants. On the other hand, according to MBC's SALUD DATA (HEALTH DATA), the population of Bogotá projected for 2020 was 8,273,319 inhabitants (regardless of the rural town of Sumapaz), which corresponds to an understatement of the population of the order of 11.61%; referring (divisor) the population estimated by the MBC to plan the COVID-19 epidemic. This implies that the amounts estimated by MBC models, to be compared with the reality reported in SALUD DATA, must be multiplied by a factor of 1.1161. This difference in population should not make a difference in the information established in the modelling of fractions of the population, but if it is of fundamental importance when the use of hospital resources is involved in modeling.

| Para meter | ASSUMPTIONS AND CONSIDERATIONS MADE BY THE MAYOR OF BOGOTÁ |
|---|---|
| $\delta_{st}$ | Likelihood (probability) of an individual in the st state recovering without worsening their clinical condition. The basic theory of probability to calculate $\delta_{st}$ may be used.<br>▪ Asymptomatic $\delta_{st=I0}$, by expert medical criterion and in accordance with [3, 5] MBC established that 30% of cases are asymptomatic and rarely reported by the authorities. As a result, 70% of the remaining cases are symptomatic.<br>▪ Symptomatic moderated $\delta_{st=I1}$, according to the report of the world health organization, 80% of the reported cases (which are assumed almost all symptomatic) are mild and moderate. This assumption implies that 80% of |

| Para meter | ASSUMPTIONS AND CONSIDERATIONS MADE BY THE MAYOR OF BOGOTÁ |
|---|---|
| | symptomatic cases (assumed very similar in magnitude to the reported cases) recover without worsening their condition.<br>▪ Symptomatic severe $\delta_{st=I2}$, it is assumed that 5 out of 7 cases with severe symptoms recover. This means that, of symptomatic cases, approximately 14.3% (similar to 13.8% reported by [6]) have severe symptoms and recover.<br>▪ Symptomatic critic $\delta_{st=I3}$, it is assumed that an individual entering the critical state has a 50% chance of recovering. That is, 2% of all cases die. This assumption is the same as that made by Imperial College (IC) [2]. |
| $\pi_{st}$ | Average recovery time, without worsening their st status:<br>▪ $\pi_{st=I0}$, according to medical criteria, an infected individual who never develops symptoms is infectious for 10 days.<br>▪ $\pi_{st=I1}$ , a person with moderate symptoms recovers on average on the eighth day of the onset of symptoms. Assumption established from the criterion of the expert physician.<br>▪ $\pi_{st=I2}$, a person occupies a general hospitalization bed 8 days before recovering. (assumed by (IC)).<br>▪ $\pi_{st=I3}$, it is estimated that a person lasts ten days in intensive care before recovering. This assumption is the same as that made by (IC). |
| $\eta_{st}$ | The average complication time of a patient in the state st<br>▪ $\eta_{st=I0}$, after the latency period, an individual takes 4.1 days to develop symptoms (taking into account the latency period, this means that the incubation period is 5.1 days, in accordance with [4])<br>▪ $\eta_{st=I1}$, from the moment an individual develops moderate symptoms, it takes 5 days to require hospitalization care (assumed by (IC)).<br>▪ $\eta_{st=I2}$, before moving to ICU a severe symptomatic spends on average six days in a general hospitalization bed (assumed by (IC)).<br>▪ $\eta_{st=I3}$, it is estimated that a person lasts ten days in intensive care before death (assumed by (IC)). |
| $\zeta_{st}$ | Contacts of infected people if there is no quarantine<br>▪ $\varepsilon_{st=I0}$, is estimated with the basic reproduction number $R_0$ equivalent to 2.6, the number of people with which an asymptomatic individual has effective contact is 7.16.<br>▪ $\varepsilon_{st=I1}$, i.e., it is assumed that people with moderate symptoms circulating freely in the population have effective contact with 10 people a day (assumed by (IC)).<br>▪ $\varepsilon_{st=I2}$, it is assumed that a hospitalized (severe symptomatic) has on average two effective daily contacts<br>▪ $\varepsilon_{st=I3}$, it is assumed that a person in intensive care has on average two effective contacts (medical expert criterion). |
| $\zeta^{Q}_{st}$ | Contacts of infected people if there is quarantine<br>▪ $\varepsilon^{Q}_{st=I0}$, it is assumed that asymptomatic people who stay at home have effective contact on average with 2.98 people per day (average number of people per household according to the 2017 multipurpose survey of the district planning secretariat)<br>▪ $\varepsilon^{Q}_{st=I1}$, it is estimated that a symptomatic individual who stays at home only has contact with the people in the household , which on average is 2.98.<br>▪ $\varepsilon^{Q}_{st=I2}$, it is assumed that a hospitalized (severe symptomatic) has on average two effective daily contacts.<br>▪ $\varepsilon^{Q}_{st=I3}$, it is assumed that a person in intensive care also has on average two effective contacts (medical expert criterion). |
| $c_{st}$ | Probability of contagion if there is no quarantine<br>▪ $c_{st=I0}$, is estimated with the basic number of reproduction $R_0$ equivalent to 2.6, the chance of contagion is 10%.<br>▪ $c_{st=I1}$, it is assumed that for each effective contact you have a possibility of contagion of 1.5%. That is, for every 200 effective contacts between a symptomatic and a moderate symptomatic individual, 3 new cases are generated on average (medical expert criterion).<br>▪ $c_{st=I2,I3}$ assumed a 1% chance of contagion for each effective contact (medical expert criterion). |
| $c^{Q}_{st}$ | Probability of contagion if there is quarantine<br>▪ $c^{Q}_{st=I0}$, possibility of contagion of 1% for each effective contact. That is, for every 100 effective contacts of a susceptible with an infectious asymptomatic in the population, a new case is generated on average.<br>▪ $c^{Q}_{st=I1}$, it is assumed that for each effective contact you have a possibility of contagion of 1.5% (medical expert criterion).<br>▪ $c^{Q}_{st=I2,I3}$, a 1% chance of contagion is assumed for each effective contact (medical expert criterion). |

**REFERENCES**


[1] Bhatraju, P. K., Ghassemieh, B. J., Nichols, M., Kim, R., Jerome, K. R., Nalla, A. K., ... & Kritek, P. A. (2020). COVID-19 in Critically Ill Patients in the Seattle Region - Case Series. New England Journal of Medicine, 382(21), 2012-2022.

[2] Ferguson, N., Laydon, D., Nedjati Gilani, G., Imai, N., Ainslie, K., Baguelin, M., ... &Dighe, A. (2020). Report 9: Impact of Non-Pharmaceutical Interventions (NPIs) to Reduce COVID-19 Mortality and Healthcare Demand.

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[5] Nishiura, Kobayashi, Miyama, Suzuki, Jung, Hayas- hi, Kinoshita, Yang, Yuan, Akhmetzhanov, and Lin- ton. Estimating the Asymptomatic Proportion of Coronavirus Disease 2019 (COVID-19) cases on Board the Diamond Princess Cruise Ship, Yokoha- ma, Japan, 2020. Osaka Institute of Public Health, 2020.

[6] World Health Organization. Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19). 2020.

To use the MBC model, the following assumptions were made with respect to transmissibility rates:

- $\beta_0$ = 0.3271875,
  Transmissibility rate of an asymptomatic individual circulating freely in the region. It was estimated in such a way that in the absence of intervention, the basic number of reproduction is equivalent to 2.6 ($R_0$ is also known as secondary infection rate or contagion rate). Value assumed by $b_0$, free movement policy.

- $\beta^Q_0$ = 0.02995 = 2.98 log(1 – 0.01) ≈ 0.0298. Difference 0.5008%
  It assumes that asymptomatic people who stay at home have effective contact on average with 2.98 people (average people per household in Bogotá, according to the DANE survey) and are assumed, a contagion probability of 0.01 for each effective contact. Value assumed for quarantine policy.

- $\beta_1$ = 0.15114 = 10 log(1 – 0.015) ≈ 0.015. Difference 0.7519%
  People with moderate symptoms circulating freely in the population are supposed to have effective contact with 10 people a day and assume that for each effective contact there is a 1.5% chance of contagion. (That is, for every 200 effective contacts between a symptomatic and a moderate symptomatic individual are generated on average 3 new cases).

- $\beta^Q_1$ = 0.04504 = 2.98 log(1 – 0.015) ≈ 0.0298. Difference 0.5008%.
  It is estimated that a symptomatic individual who stays at home only has contact with the people in the household. Value assumed for quarantine policy.

- $\beta_2$ = 0.0201 = - 2.00 log(1 – 0.015) ≈ 0.02. Difference 0.5008%.
  It is assumed that a hospitalized (severe infected) has on average two effective daily contacts, with a chance of contagion of 1% for each effective contact (medical expert criterion). This probability is lower than that assumed for a moderate infected as biosecurity measures are assumed.

- $\beta_3$ = 0.0201 = - 2.00 log(1 – 0.015) ≈ 0.02. Difference 0.5008%.
  It is assumed that a person in intensive care also has on average two effective contacts (medical expert criterion).

According to Mejia Becerra et al. (2020), the assumptions raised by MBC represent the most pessimistic estimates of academic literature. In short, the parameters used are:

1. General Parameters:
   The following table presents general biological parameters:

| GENERAL BIOLOGICAL PARAMETER – MBC SEIR3D MODEL | | | | |
|---|---|---|---|---|
| **Parameter** | **OPTEX Parameter** | **Description** | **Value** | **Measurement Unit** |
| $\mu^N$ | MIUN | Natural mortality rate | 0.00005 | fpo/day |
| $\kappa$ | KAPP | The latency period of the virus before developing | 1 | day |
| $\mu$ | MIUUB | Epidemic mortality rate | 0.001 | fpo/day |
| $\omega$ | PCONB | Probability of that a person may be contagion | 1/$\kappa$ | prob |

2. Epidemic State Dependent Parameters:
   The following table presents epidemic state dependent parameters:

| STATE DEPENDENT BIOLOGICAL PARAMETER – MBC SEIR3D MODEL | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **State** | $\beta_{st}$ | $\beta^Q_{st}$ | $\delta_{st}$ | $\pi_{st}$ | $\eta_{st}$ | $\zeta_{st}$ | $\zeta^Q_{st}$ | $c_{st}$ | $c^Q_{st}$ |
| | **Transmissibility** | | **Probability** | **Time (day)** | | **Contacts/day** | | **Probability** | |
| | | | | **Recovery** | **Complication** | | | | |
| I0 | 0.3271875 | 0.02995 | 0.3000 | 10.0 | 4.1 | 7.16 | 2.980 | 0.10 | 0.010 |
| I1 | 0.15114 | 0.04504 | 0.8000 | 8.0 | 5.0 | 10.00 | 2.980 | 0.015 | 0.015 |
| I2 | 0.0201 | 0.0201 | 0.7143 | 8.0 | 6.0 | 2.00 | 2.000 | 0.01 | 0.01 |
| I3 | 0.0201 | 0.0201 | 0.5000 | 10.0 | 10.0 | 2.00 | 2.000 | 0.01 | 0.01 |

The parameter values of $\beta_{st}$ and $\beta^{Q}_{st}$ are those calculated with the formulas previously presented

3. Initial Conditions:
   The following table presents the initial conditions (fraction of the population in each epidemic state)

| INITIAL CONDITIONS: – MBC SEIR3D MODEL | | |
|---|---|---|
| **State** | **Population Fraction** | **Population** |
| I0 | 0.000030352084176 | 225 |
| I1 | 0.000015513287468 | 115 |
| I2 | 0.000000134898152 | 1 |
| I3 | 0 | 0 |
| RE | 0 | 0 |
| ND | 0 | 0 |
| ED | 0 | 0 |
| EX | 0.000026979630379 | 200 |
| SU | 0.999927020099825 | 7'412,459 |
| TOTAL | 1 | 7'413,000 |

MBC calibrated the model in such a way that as of March 31, there are about 6 deaths.

### 1.5. SCENARIOS ANALYZED BY MAYOR OF BOGOTA CITY

MBC study considered , three scenarios of decisions:

1. No action is taken.

2. There is 30% isolation from 15 March to 20 March, from this date it is assumed that there is an isolation of 60% until 27 April, from where isolation of 30% for the susceptible and 50% for moderate symptomatic is maintained. There is 30% isolation from 15 March to 20 March, then it is assumed.

3. There is 30% isolation from 15 March to 20 March, then 70% isolation is assumed for three months: from 20 March to 20 June and 30% isolation for asymptomatic and 50% for symptomatic from this date.

The simulated period was one year. The values assumed for $\theta_{t,st}$ in the scenarios are presented in the following table (t in days):

| State st | Scenario 1 | | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|---|---|
| | Period | $\theta_{t,st}$ | Period | $\theta_{t,st}$ | Period | $\theta_{t,st}$ |
| **I0** | $\forall$t | 0 | $0 \le t < 5$ | 0.3 | $0 \le t < 5$ | 0.3 |
| | | | $5 \le t < 43$ | 0.6 | $5 \le t < 97$ | 0.7 |
| | | | $43 \le t$ | 0.3 | $97 \le t$ | 0.3 |
| **I1** | $\forall$t | 0 | $0 \le t < 5$ | 0.3 | $0 \le t < 5$ | 0.3 |
| | | | $5 \le t < 43$ | 0.6 | $5 \le t < 97$ | 0.7 |
| | | | $43 \le t$ | 0.5 | $97 \le t$ | 0.5 |

### 1.6. RESULTS

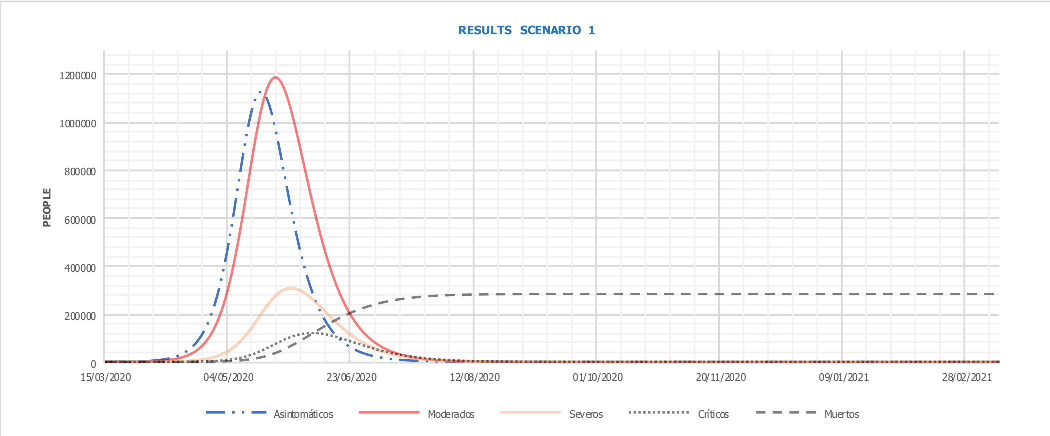
The model used by MBC serves to understand the dynamics of the transmission of a disease such as COVID-19 in the city of Bogota and the effects of isolation policies. While this aggregate model is conceptually appropriate to explain the dynamics of the transmission, the uncertainty of various sensitive parameters and the lack of: i) regionalization and ii) an age group structure, make this model a tool for qualitative evaluation of intervention actions in hypothetical decision-making scenarios, rather than as a model to support decision-making with high precision and optimization criteria.

#### 1.6.1. SCENARIO 1. NO QUARANTINE

This scenario shows a high number of deaths, severe cases, and critical patients who according to the MBC would surely have saturated the health system as of April 14. Results of projection on the stage without quarantine. $R_t$ symbolizes the effective number of transmission calculated by MBC with the next generation matrix method (). The results presented by the MBC are presented below

| Día | Susceptibles | Expuestos | Asintomáticos | Moderados | Severos | Críticos | Recuperados | Muertos | $R_t$ |
|---|---|---|---|---|---|---|---|---|---|
| 7/04/2020 | 7390210 | 3126 | 8729 | 5006 | 678 | 124 | 5092 | 35 | 2.59 |
| 14/04/2020 | 7344217 | 9338 | 26172 | 15057 | 2047 | 377 | 15678 | 114 | 2.58 |
| 21/04/2020 | 7209022 | 27198 | 77112 | 44767 | 6124 | 1136 | 47285 | 356 | 2.53 |
| 28/04/2020 | 6832922 | 73685 | 215996 | 128741 | 17921 | 3369 | 139289 | 1076 | 2.40 |
| 05/05/2020 | 5929707 | 165011 | 528704 | 338317 | 49377 | 9606 | 389106 | 3170 | 2.00 |

According to MBC, this scenario has a maximum overall hospitalization demand of 306,370 on May 30, 2020 and a peak of critical cases on June 7 (124,346 critical cases). In addition, the disease would reach 90.5% of the population, leaving 283,532 deaths during the testing period (one year).

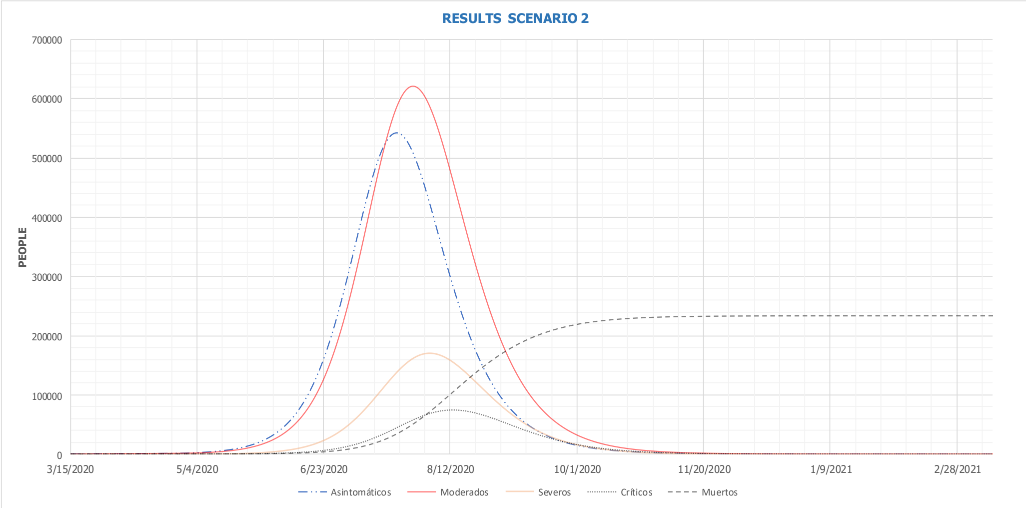



### 1.6.2. SCENARIO 2. QUARANTINE UNTIL APRIL 27

In this hypothetical scenario there is a substantial decrease in demands for health resources at the peak of the epidemic and a postponement of this compared to the previous scenario. It is estimated that 300 critical cases are exceeded on 19 May; the number of individuals who have severe symptWHO in this scenario amounts to 170. 913 cases on 4 August and 74520 critical cases on 13 August. It is appreciated that the decrease in cases is given to a greater magnitude by measures that persist over time; deferral of demand for health resources takes place to a greater extent through mandatory preventive isolation. In this scenario, the virus affects approximately 75.5% of the population leaving 233,352 dead during the testing period.

The results presented by MBC are presented below

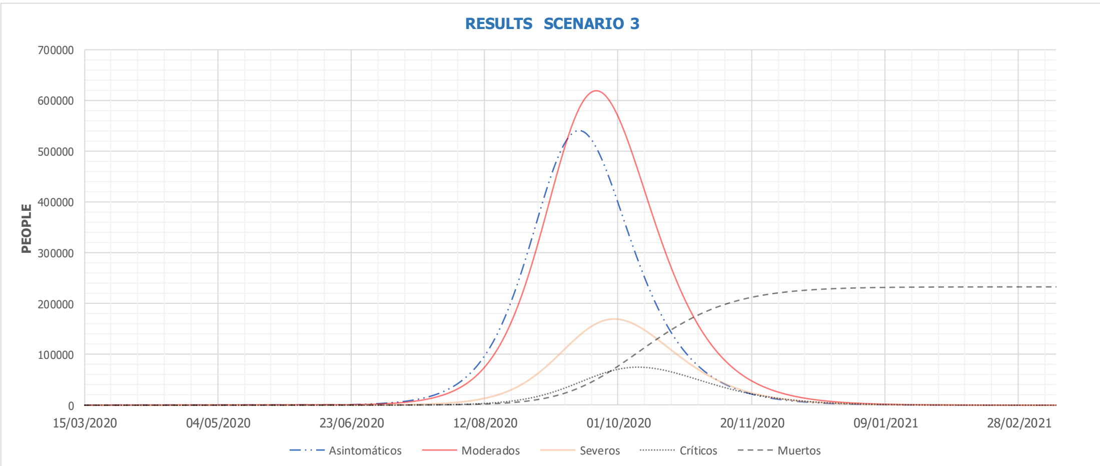
| Día | Susceptibles | Expuestos | Asintomáticos | Moderados | Severos | Críticos | Recuperados | Muertos | $R_t$ |
|---|---|---|---|---|---|---|---|---|---|
| 7/04/2020 | 7410025.31 | 147.32 | 631.98 | 623.35 | 140.10 | 40.93 | 1373.05 | 17.96 | 1.33 |
| 14/04/2020 | 7408827.28 | 185.52 | 794.32 | 784.74 | 182.28 | 59.46 | 2130.90 | 35.50 | 1.32 |
| 21/04/2020 | 7407318.53 | 233.59 | 999.89 | 987.56 | 231.70 | 79.65 | 3089.30 | 59.78 | 1.32 |
| 28/04/2020 | 7405292.29 | 375.18 | 1301.63 | 1245.66 | 292.52 | 102.96 | 4298.14 | 91.62 | 1.83 |
| 05/05/2020 | 7401082.00 | 740.00 | 2536.00 | 1969.00 | 399.00 | 134.00 | 6017.00 | 134.00 | 1.00 |




### 1.6.3. SCENARIO 3. QUARANTINE UNTIL JUNE 20

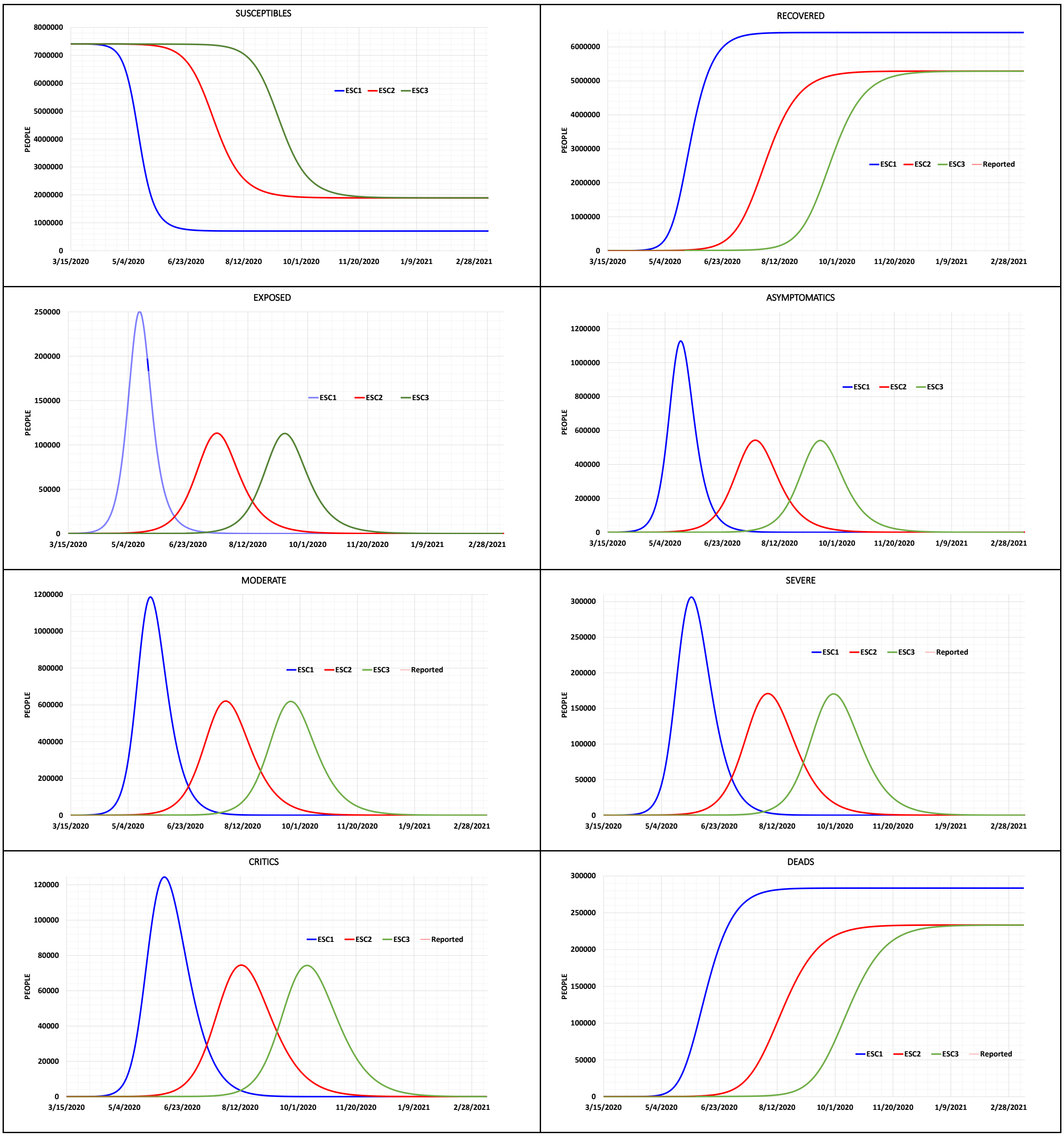
This scenario follows a logic analogous to that of the previous scenario; only the length of mandatory preventive insulation is increased until 20 June and the effectiveness of the mandatory preventive insulation is increased (to 70%). Figure shows the results through April 28 of this scenario. The difference between this scenario and 2 lies in the postponement of the highest demand for health resources. Maintaining maximum demands at similar levels: 170416 severe cases on September 30. 74318 critical cases on October 9. 300 critical cases are exceeded on 14 July and the epidemic affects approximately 75.5% of the population, leaving 233270 dead during the testing period.

| Día | Susceptibles | Expuestos | Asintomáticos | Moderados | Severos | Críticos | Recuperados | Muertos | $R_t$ |
|---|---|---|---|---|---|---|---|---|---|
| 7/04/2020 | 7410673.79 | 86.21 | 408.82 | 461.26 | 115.53 | 36.62 | 1200.71 | 17.05 | 1.11 |
| 14/04/2020 | 7410038.72 | 93.30 | 440.60 | 498.31 | 131.24 | 48.07 | 1717.82 | 31.95 | 1.11 |
| 21/04/2020 | 7409351.41 | 100.98 | 476.38 | 538.28 | 144.20 | 57.09 | 2281.24 | 50.41 | 1.11 |
| 28/04/2020 | 7408607.49 | 109.30 | 515.48 | 582.02 | 156.76 | 64.60 | 2892.61 | 71.74 | 1.11 |
| 05/05/20 | 7407802.00 | 118.0 | 558.00 | 630.00 | 170.00 | 71.00 | 3556.00 | 96.00 | 1.00 |

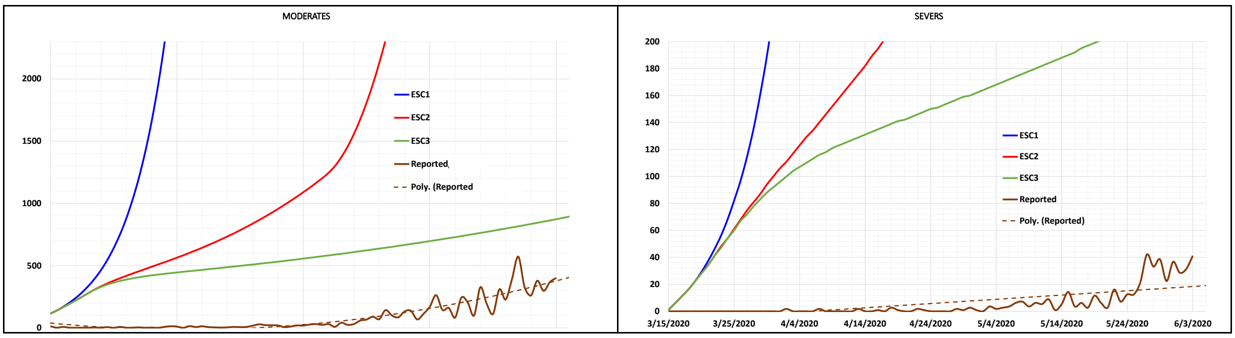


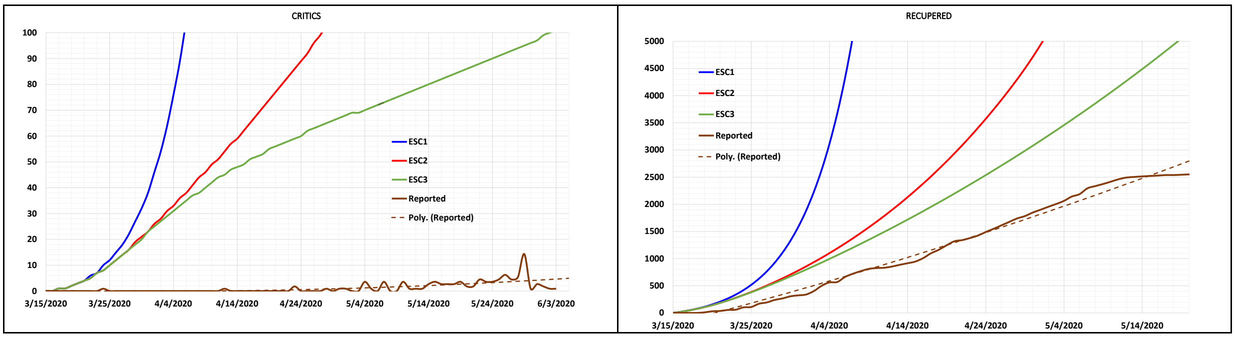

### 1.6.4. AGGREGATE ANALYSIS

To develop comparative curves with reality, historical data were divided by 1,1161, this due to the difference between the population data of the MBC which according to SALUD DATA is outdated. Below is the system behavior for each of the epidemiological states of the SEI3RD model.




The following graphs present the comparison of the results of the scenarios analyzed by MBC and the reality reported by the same MBC.






The significant difference between the states "predicted" by the MBC and reality, reported by the MBC, reaffirms that "the most pessimistic estimates of academic literature" (Mejía Becerra et al., 2020) have been used, which may force governments to take very drastic (draconian) actions with high economic impact.

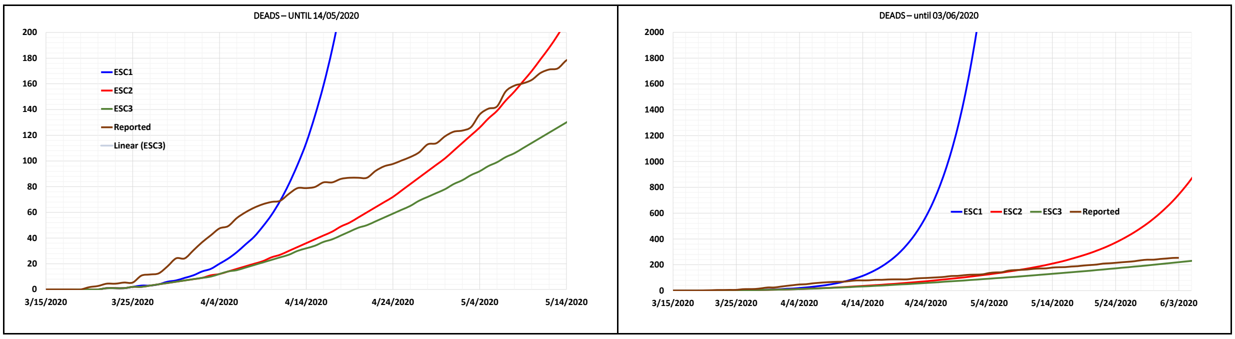
These models are based on exponential growth that, with a constant $R_0$ number above 1, may predict that the majority of the population would become critically infected, which would then quickly result in a large number of deaths. Historic data seems to indicate that the behavior of "curves" is not exponential, rather sub-exponential; this, which seems to be a simple technical characterization; but, it has very important, in this case transcendental, implications.

When using simulation models, in most cases, scenario analysis is used by to test the impact of decisions and not so much to analyze uncertainty. In this case, it seems that the reality is totally out of the way for the MBC, this entails serious implications, since this situation implies that it faces at least one of the following situations:

- The mathematical model describing the epidemic used is not the appropriate
- Computational implementation of the mathematical model may have errors
- The biological and socio-demographic parameters used for simulation are not appropriate
- Measurements representing the historical sample do not correspond to reality.

If all is correct, the representativeness of the mathematical model would be appropriate and its support for decisions will be effective.

The following graphs present the results for the dead.



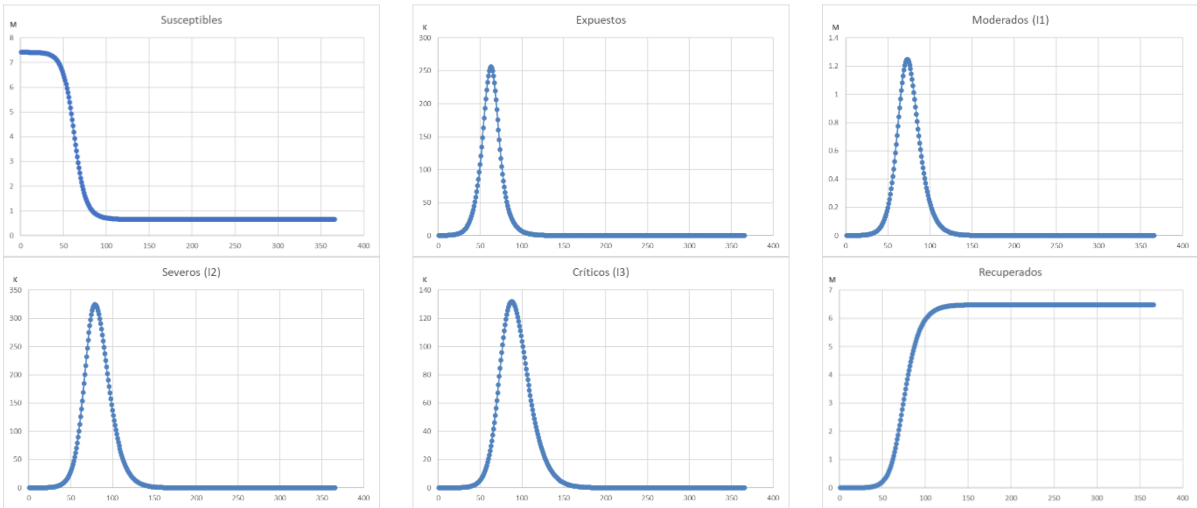

In the case of deaths, reality outperforms the most drastic scenario, this happens from the beginning of the simulation. There can be many reasons, it should be borne in mind that it appears that the initial conditions of the model influence the death toll, it should be remembered that the MBC calibrated the model in such a way that as of March 31 there are about 6 deaths.

The graphs presented were constructed with information taken from:

- Mejía Becerra. J. D. Modelación Matemática de la Propagación del SARS-CoV-2 en la Ciudad de Bogotá Segunda Versión. https://observatoriocovid19.sv/doc/biblioteca/internac/Ficha_Metodologica.pdf y
- Base de datos de casos confirmados COVID-19. Subsecretaría de Salud Pública. Secretaría Distrital de Salud. 2020. Corte: 10 de junio 2020.

## 1.7. COMPARISON WITH BOGOTÁ OFICIAL MODEL

This experiment is based on reproducing the results published by the Mayor of the city of Bogotá (MCB) for the SEI3RD model, as the official model used to manage the COVID-19 pandemic. Scenario 1 reported by MCB was reproduced, which does not consider confinement or mitigation policies. The reference population is 7'413,000. The results are presented below and are the same as those reported by MCB.




# 2. CASE: MADERO - TAMPICO - ALTAMIRA

# 3. FUNDING

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