The Effect of Trust in the containment of Covid-19 in Colombia

by

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Abstract

Covid 19 is a reality today in Colombia, and a lot of decisions are being taken by the government daily to prevent the virus from spreading at high rate, sadly Colombian government has not acted right in the past, leading to lacks of trust in it by the people, and nowadays its even worse with how they are managing the crisis. This document focuses on that lack of trust and evaluates how it affects the development of a pandemic like the one we are facing, with the help of System Dynamics. Based on theory about our authors, we demonstrated that the pandemic is a Large-Scale social dilemma where communication is a very important subject, because it can determine how the pandemic develop. We managed to create a simulation model that helps us know how trust is involved in our reality at facing the virus and make valid conclusions on how is Colombia doing in all this situation.

1. Problem Statement

The world has responded to the on-going COVID-19 pandemic in a significant way. Many countries have invested in testing citizens who are possibly infected by the disease; isolating those who test positive, and tracing and testing those who have come into contact with the infected. Also, most countries have instituted regulations requiring physical distancing or home isolation, encouraging citizens to avoid contact with others to stop the spread of the disease. There is also a world-wide effort by scientists to quickly develop a vaccine. We also have to consider the fact that trust among people have deteriorated in most of the latin american countries, and Colombia is no exception, this because government has not taken effective actions against the crisis, and also because they don't know what to communicate to the people, something people have not really thought. With our research we managed to determine that's a key factor in a crisis like a pandemic, mostly because it starts becoming a Large-Scale social dilemma, therefore it is crucial to know what to communicate and when, the problem is Colombian government has made a poor work in that area, leading to less trust and higher infection rates, being that problematic our aim of solution.

Several organizations collect data on the number of confirmed COVID-19 confirmed cases of each country, including the number of confirmed deaths; for example, Our World in Data collects such information and makes it publicly available on its website.[1]

To study the pandemic, we developed a simple System Dynamics SIR (susceptible-infected-recovered) epidemic model. We added sub-models for regulated and voluntary precautions such as shelter-in-place orders; physical distancing; quarantine and isolation; wearing masks; and frequent hand-washing. Also, this model allows for a varying fatality rate that might occur as additional information about the virus's characteristics and effects become available.

2. Method and materials

System Dynamics is a computer simulation technique based on solving a highly interconnected system of differential equations.[2] A model can be viewed as a series of Stocks (boxes) that contain entities and connected Flows (pipes with valves) that increase and decrease the value of the stocks over time. Control variables use the information about the Stocks to manage the Flows. The model being discussed in this paper can be visualized using the special purpose software Vensim[3] (see Figure 1). The model has also been implemented in Microsoft Excel[4] to do the data fitting and to present the results in this study.

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[1] Our World in Data, Coronavirus Pandemic (COVID-19).
[2] https://www.systemdynamics.org/what-is-sd
[3] https://vensim.com/coronavirus/
[4] Albright, S. Christian, *VBA for Modelers: Developing Decision Support Systems with Microsoft Excel*, 5th Edition, South-Western College Publications, 2015.

The model begins with an initial number of infected people and an initial number of susceptible people. There is an uncontrolled reproduction rate, defined as the number of people a person with the virus will infect during his or her illness - that is, affected by regulated and voluntary precautions that attempt to prevent the spread of the virus. This modified reproduction rate is then divided by the illness duration to obtain a reproduction rate per day, per infected person. This daily reproduction rate is multiplied by the number of people infected and modified by the fraction of people still susceptible, to determine the outflow of persons from the susceptible population into the infected population. Infected people will eventually flow into either the death or the recovered groups based on the fatality fraction divided by the duration of the illness.

The simulation uses a starting point of March 2020. The possibility of COVID-19 becoming a pandemic was recognized by late March and the precautionary regulations in most jurisdictions came into effect in early April; however, they took a certain length of time to be fully implemented. And although the regulations were to be in effect for a limited amount of time, once eased or removed, some people continued to take precautions voluntarily. These voluntary precautions are assumed to continue indefinitely. Finally, the fatality fraction is assumed to change over time as more is learned about the virus, including how to protect the most vulnerable portion of the population (such as the elderly or those with compromised immune systems). These are the current approaches for reducing the impact of the COVID-19 pandemic.[5]

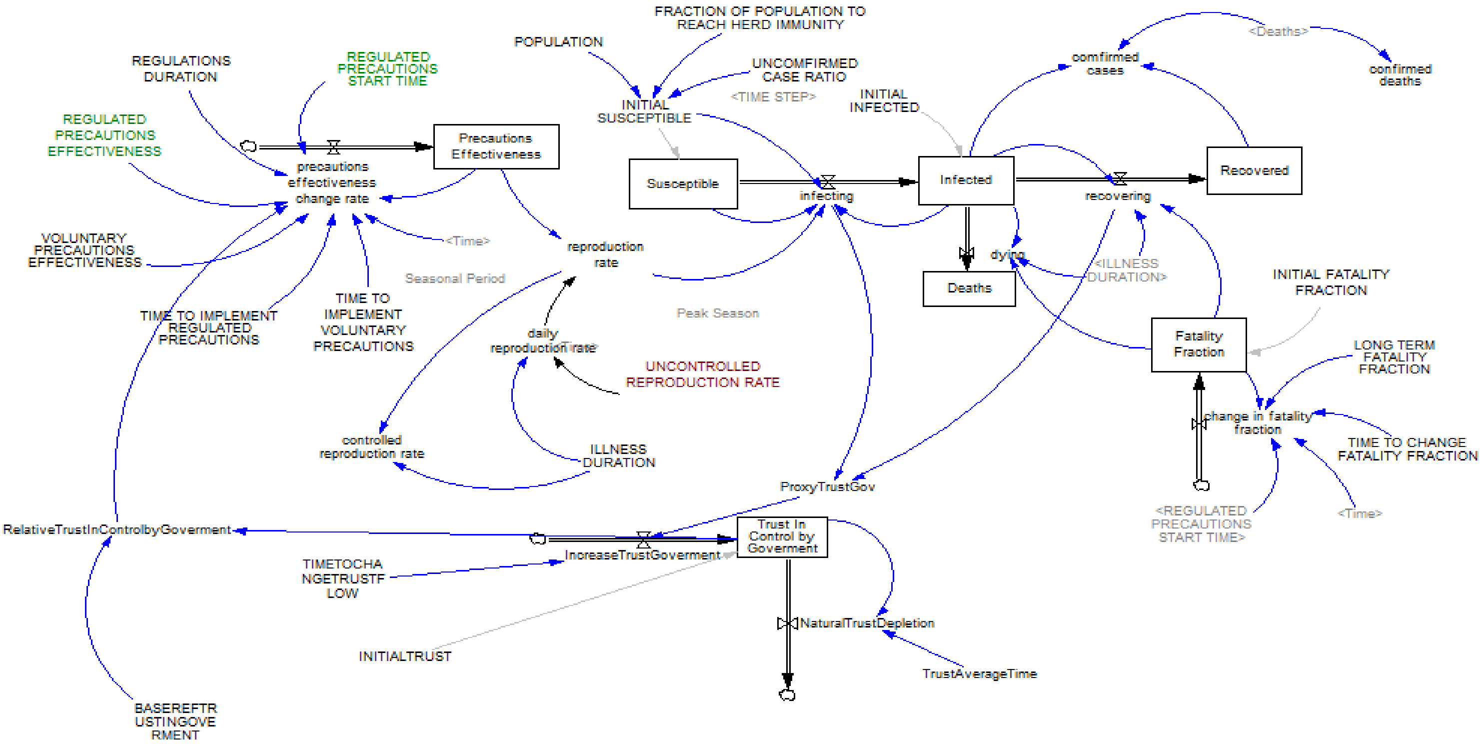
Lastly, data for ***Colombia*** on the number of confirmed cases and the number of confirmed deaths is used to estimate the parameters of the model.

To develop this study, we followed the next steps:

1. Simulation Model: We started involving in the original model the trust factor in order to check if it had any impact on the development of the model.
2. Literature analysis: Based on those results, we then looked for literature that supported them.

[5] The equations used in the model are provided in Annex A.

3. Results: We extracted the results obtained in the simulation supported by the literature, with their analysis.
4. Discussion: Taking into account our inputs with this project, we evaluated similar results in the literature analysis we did previously, so we could discuss why those results matter.



5. Conclusions: Already having results supported by literature, we then started making our own conclusions on the subject and in how trust affects in the development of a pandemic.

Figure 1: Stock and Flow Diagram of a Simple SIR Epidemic Model

The model shows us a great cycle that shows that if we have confidence in the government's controls there would be a cooperation that would help to improve the effectiveness of the precautions thus decreasing the infected which would increase the recoveries which in turn help people to trust.

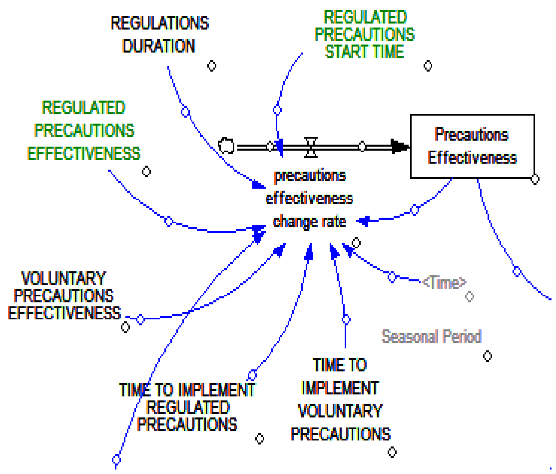


Figure 2: Diagram of precautions effectiveness

In the effectiveness of the precautions that are being applied, we take into account the time factor, where we look at the beginning of the imposed precautions and add up the time these take.
If Then Else(Time<Regulated Precautions Start Time, 0, If Then Else(Time<=(Regulated Precautions Start Time+Regulations Duration)
We also want to see what happens if there is relative confidence in the government's controls given the effectiveness of the precautions if they are voluntary and how long they can be implemented voluntarily.

(Relative trust in control by government*(Voluntary Precautions Effectiveness-precautions Effectiveness)/Time To Implement Voluntary Precautions)

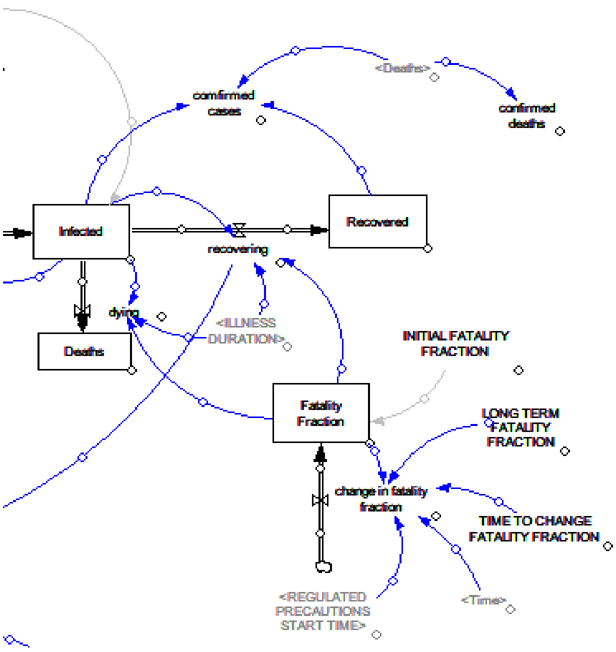


Figure 3: Diagram of recovered and death people

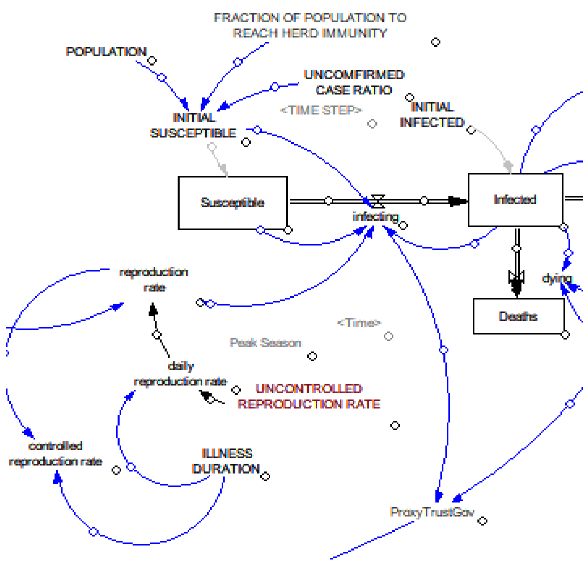


Figure 4: Diagram of infection and infection reproduction

Figure 5 shows the infection where it takes into account the people susceptible to infection, the daily infected, the general, the recovered and the dead and makes a comparison between the infected with those who recover and the infected with those who die. (Infecting-Dying-Recovering)**.**

Figure 4 takes into account the people who are susceptible to the epidemic as it is known are vulnerable people with respiratory problems, older people, etc. These are taken into account as well as possible infected that are not yet tested or confirmed even those which involve a dangerous source of infection as it is not fully safe that how many infected actually have, in turn considering people who might be immune to it.

(Population*Fraction Of Population To Reach Herd Immunity/Unconfirmed Case Ratio)

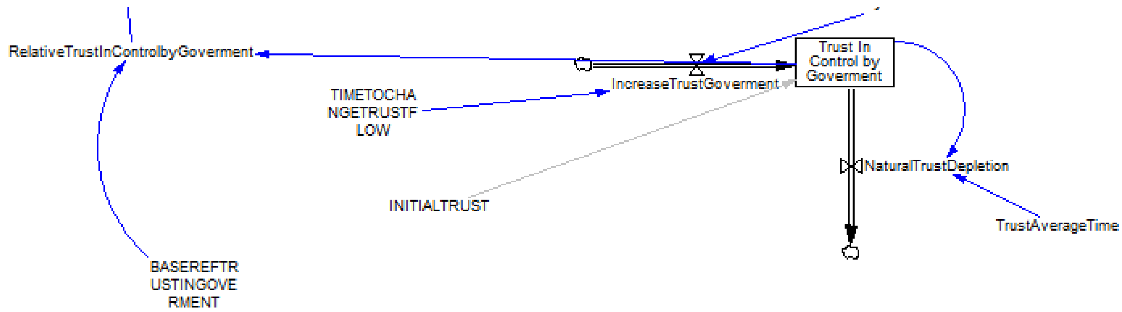


Figure 5: Diagram of Trust

Figure 5 looks at the trust that varies over time, the natural trust we all have, and how this can have an effect on the trust we have in the controls the government is implementing. (IncreaseTrustGoverment-NaturalTrustDepletion).

We also look for ways to increase this confidence, and we think of a proxy variable that can generate confidence from the behaviour of those infected and recovered and a time that can change the flow of confidence. (ProxyTrustGov/Timetochangetrustflow)

2.1 Assumptions

For this model, the following assumptions were introduced:

- for each confirmed case of COVID-19, there are 10 confirmed cases that are not confirmed;
- the initial number of susceptible people is the 7% of the population which is the number of confirmed cases to have the recovered population represent 70% of the entire population, and therefore to obtain herd immunity;
- the uncontrolled reproduction rate and the initial fatality fraction are estimated based on the available time-series data;
- the duration of the illness is 21 days on average;
- the possibility of a pandemic was only gradually recognized in March 2020;
- the precautionary regulations started around April 1st and were gradually lifted around June 1st but the actual values used in the model are estimated based on the available time-series data;
- the effectiveness of the regulations varied over time because it took several days for them to fully come into effect;
- both the effectiveness of the regulations and the time to fully implement them are estimated based on the available time-series;
- the fatality fraction began to change when the regulations were first implemented, and then over several days it gradually settled into a long-term fatality fraction;
- the long-term fatality fraction and the time it takes to reach that point are estimated based on the time-series data;
- after the regulations were lifted the population eventually took voluntary precautions; and
- finally, the effectiveness of the voluntary precautions and the time it took for the population to adjust are estimated based on the time-series data.

3. Theory/Calculation

3.1Estimating the Model Parameters

First, time-series data for ***Colombia*** for the cumulative number of confirmed deaths and the cumulative number of confirmed cases were collected. Then, the uncontrolled reproduction rate, the effectiveness of the regulated and voluntary precautions, and their implementation times were calculated estimated by minimizing the sum of squared error between the data and the model for the cumulative confirmed cases. Then, the initial fatality fraction, the long-term fatality fraction, and the time to reach the long-term fatality fraction were estimated by minimizing the sum of squared error between the data and the model for the cumulative confirmed deaths. The data fits are shown graphically in Figures 2 and 3.

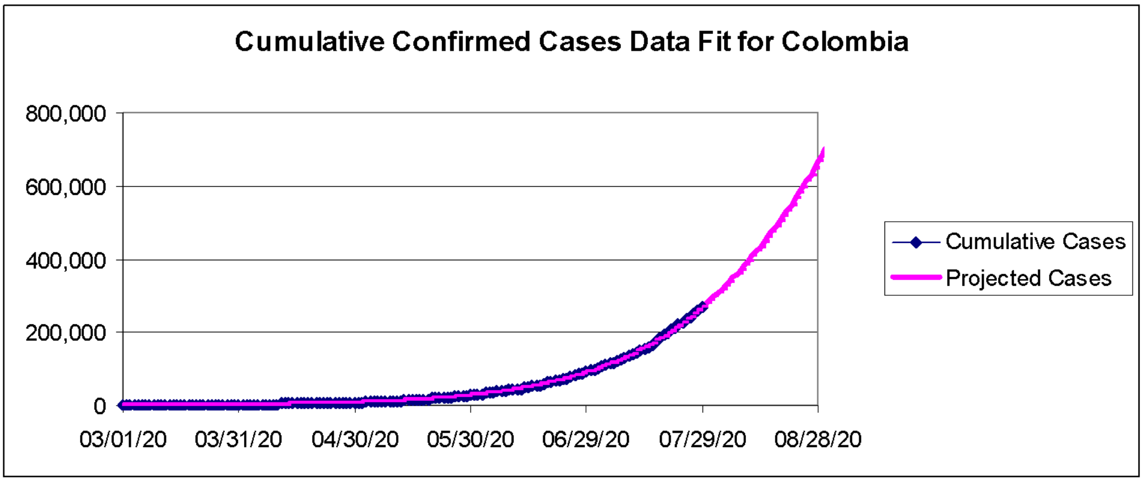


Figure 5: Confirmed Cases Time-Series and Model Behaviour Over Time in ***Colombia***

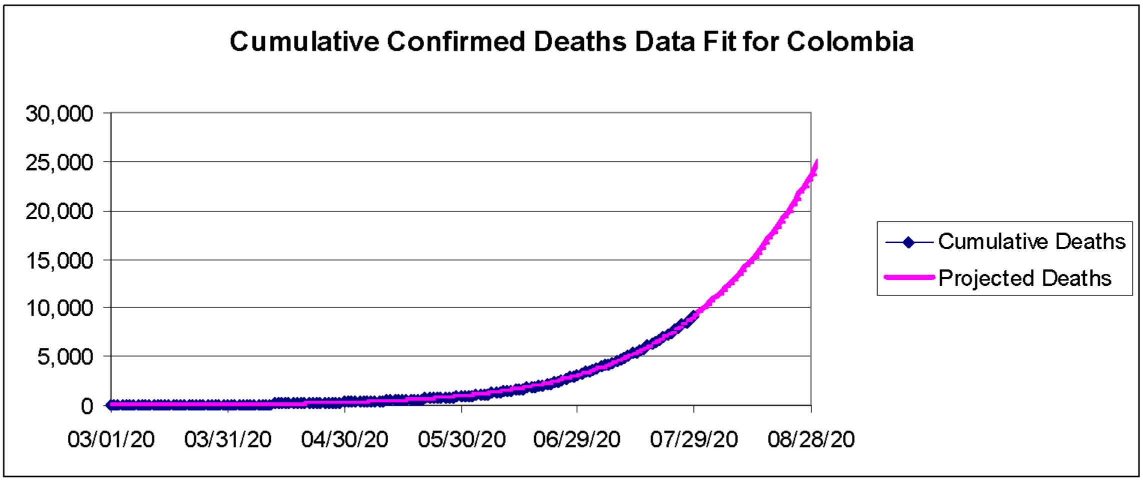


Figure 6: Confirmed Deaths Time-Series and Model Behaviour Over Time in ***Colombia***

Figures 7 and 8 show the daily data on confirmed cases and confirmed deaths compared to the model results.

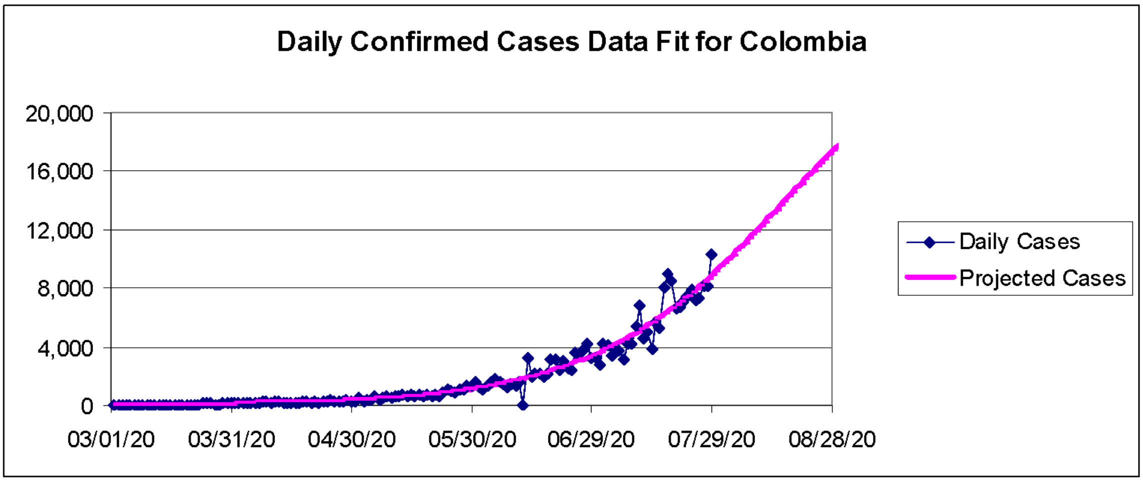


Figure 7: Daily Confirmed Cases Time-series and Model Behaviour Over Time in ***Colombia***

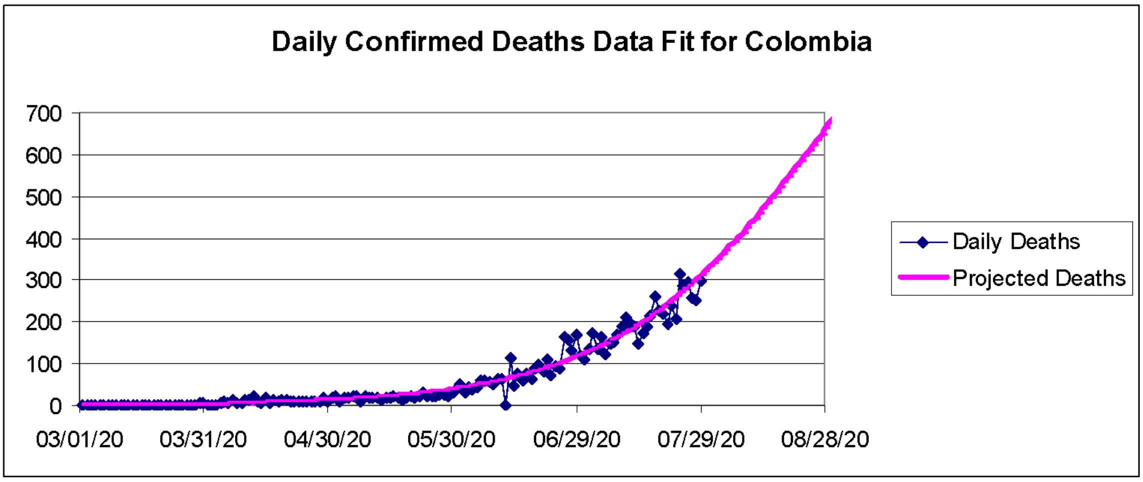


Figure 8: Daily Confirmed Deaths Time-series and Model Behaviour Over Time in ***Colombia***

Table 1 shows the parameter values that were used to fit the model to the data, along with the short-term projections of confirmed cases and confirmed deaths from the model.

Table 1: Parameters and Short-Term Projections from the ***Colombia*** Model

Parameter	Estimate
Uncontrolled Reproduction	***5.8***
Initial Fatality Rate	***7%***
Regulated Precautions Effectiveness	***68%***
Estimated Date Regulations Came Into Effect	***04/06/20***
Days to Implement Regulated Precautions	***3***
Voluntary Precautions Effectiveness	***70%***
Estimated Date Regulations Were Lifted	***06/06/20***
Days to Implement Voluntary Precautions	***55***
Long-Term Fatality Rate	***2.3%***
Days to Obtain Long-Term Fatality Rate	***365***
Projected Confirmed Cases by August 1st, 2020	***295,000***
Projected Confirmed Deaths by August 1st, 2020	***10,200***

It appears Colombia got a late start in coming to terms with the epidemic. If it had reacted even a week earlier, the results might have been significantly different and the spread of the virus might have been controlled.

4. Results

4.1 Long-Term Projections

The System Dynamics approach attempts to understand the physics of a problem (such as, an epidemic) and hypothesizes cause and effect. For this model, historical data was used to estimate the parameters that provide the best fit (i.e., by minimizing the sum of squared error). Although this approach does not produce a confidence interval on the results, the cause and effect approach and the quality of the data fit provide confidence in using the model to project the results into the longer-term.

The parameters shown in Table 1 were used to make long-term projections. Table 2 shows the long-term reproduction rate, and the long-term cumulative confirmed cases and confirmed deaths in ***Colombia*** projected by the model. ***The long-term reproduction rate is above 1.0. This suggests COVID-19 will continue to grow exponentially in Colombia, unless some action is taken.***

Table 2: Long-Term Projections from the ***Colombia*** Model

Parameter	Estimate
Long-Term Reproduction Rate	***1.75***
Projected Confirmed Cases by January 1st, 2021	***2,400,000***
Projected Confirmed Deaths by January 1st, 2021	***120,000***

Figures 6 and 7 show the long-term model projections for ***Colombia*** graphically. ***The curves show the cumulative confirmed cases and confirmed deaths are projected to eventually flatten out once Colombia reaches herd immunity in the early new year.***

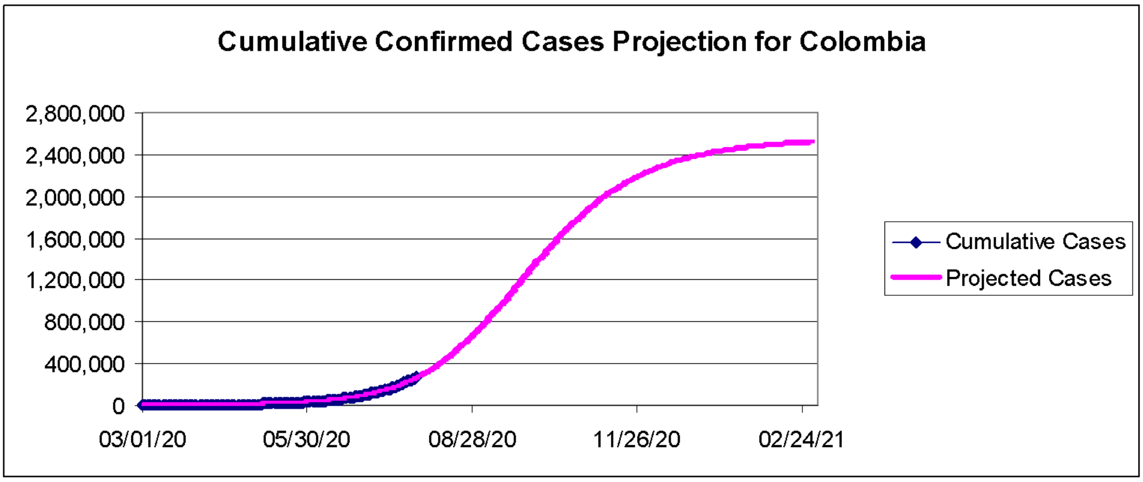


Figure 9: Long-Term Projection for Cumulative Confirmed Cases in ***Colombia***

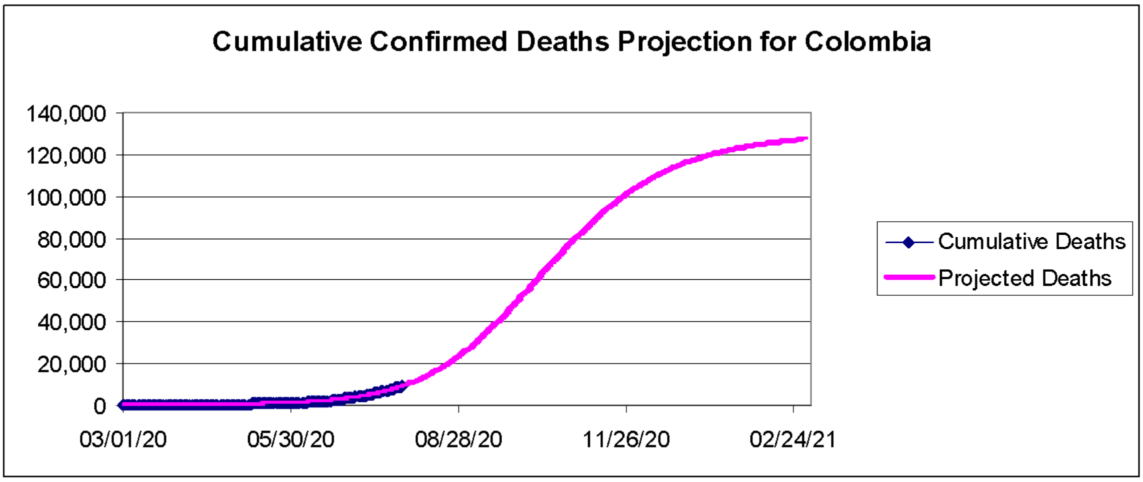


Figure 10: Long-Term Projection for Cumulative Confirmed Deaths in ***Colombia***

It may be easier to interpret the results using the weekly projections shown in Figures 11 and 12. ***It appears the number of confirmed cases and confirmed deaths per week has been increasing exponentially since the epidemic started in Colombia. The model projections suggest the number of confirmed cases and confirmed deaths will reach a peak in early September.. Then the weekly confirmed cases and confirmed deaths will begin to decline. However, the epidemic will still be a major concern in Colombia into 2021.***

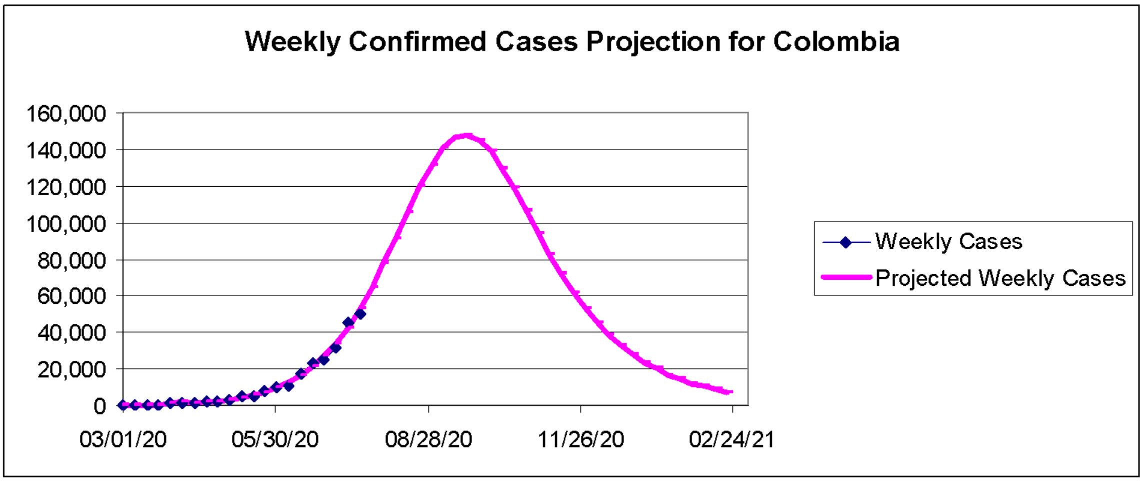


Figure 11: Long-Term Projection for Weekly Confirmed Cases in ***Colombia***

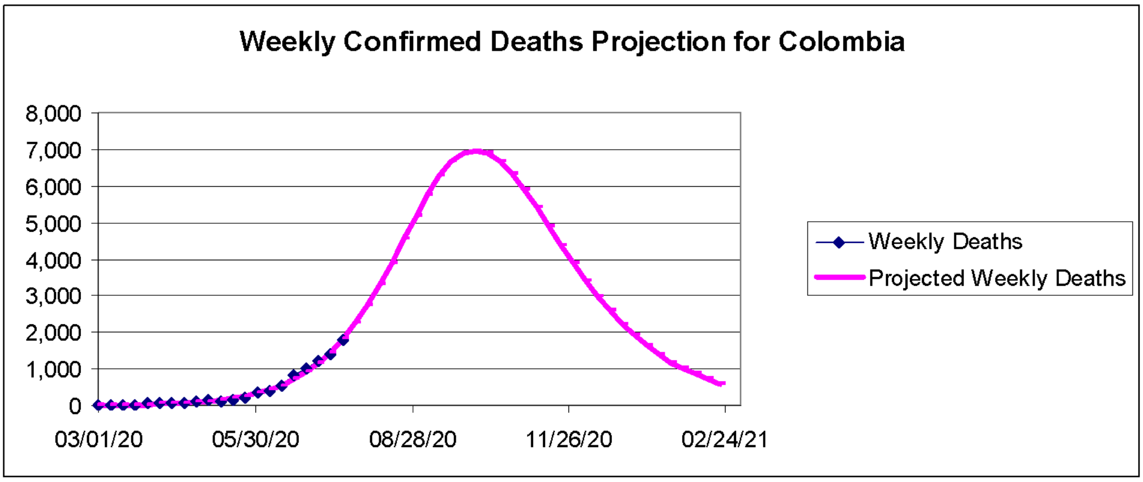


Figure 12: Long-Term Projection for Weekly Confirmed Deaths in ***Colombia***

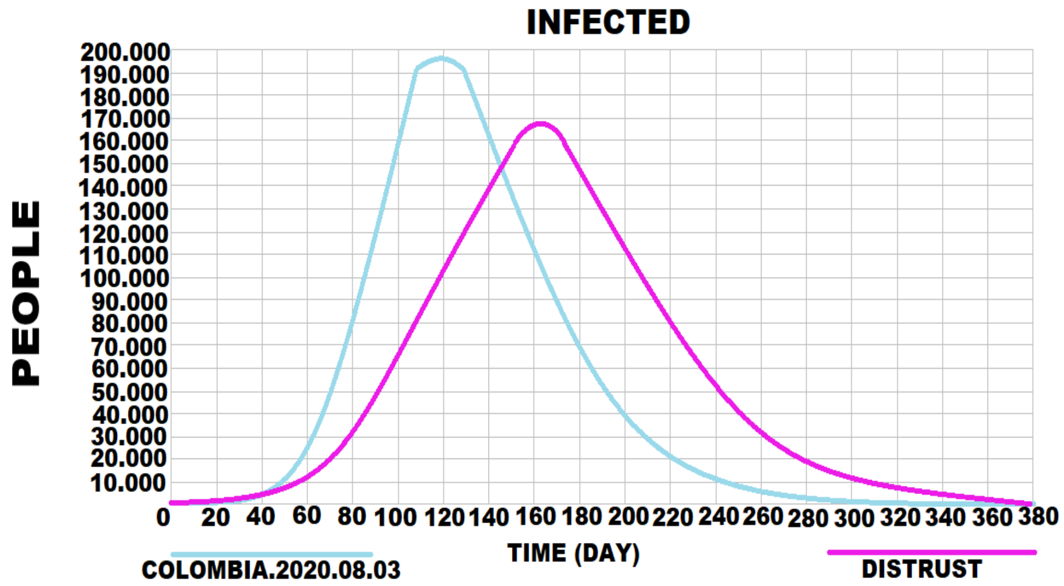


Figure 13: Infection in Colombia taking into account a variable of distrust from deaths as an assumption

Taking into account the two figures in reference, if levels of distrust get too high, meaning we wait till government reach a high number of deaths, people will start cooperating, and the infection rate will be minimum, because people trust when they see that what government says it's true.

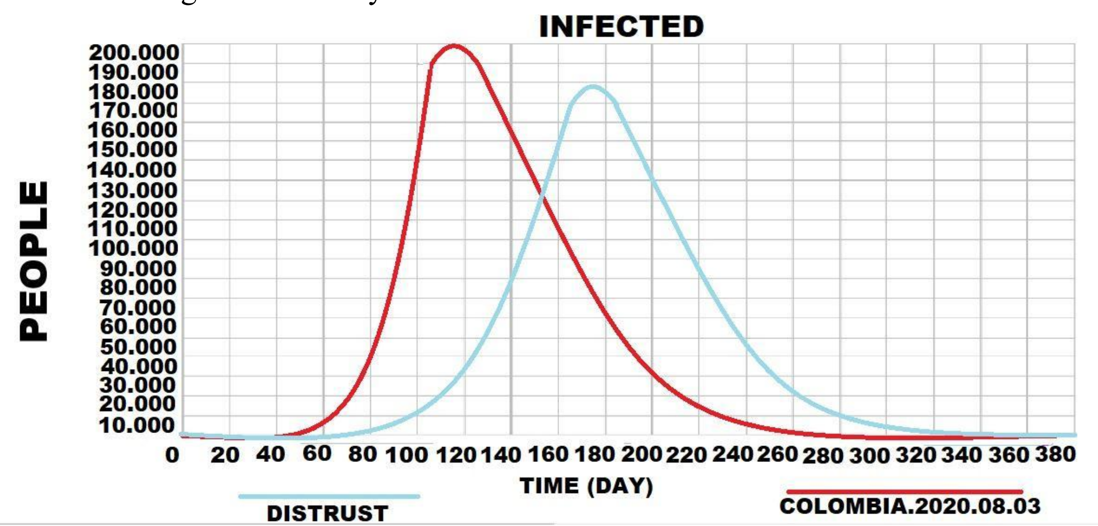


Figure 14: Infection in Colombia taking into account a variable of distrust from infected as an assumption

Talking about the behaviour of the graphic trust, precaution development and their effectiveness, all affect the infection rate, that's why it's always important to analyse trust in the development of a pandemic.

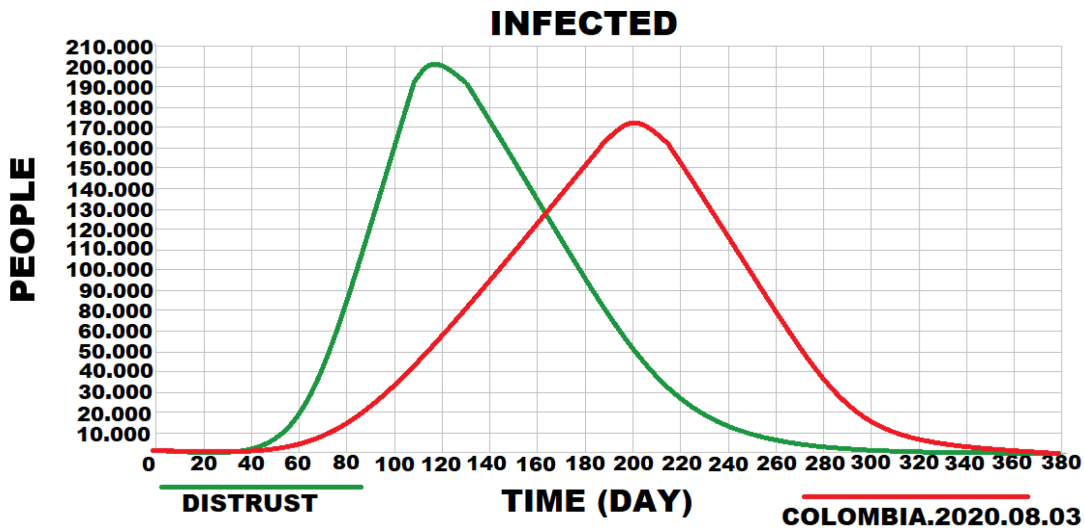


Figure 15: trust connected with the number of infected per day

In figure 15 we can see how trust would have affected the number of infected people in Colombia, and helps us understand that not every variable we link trust to end in the same results. For example, in this figure we see that if people trust were affected by the number of infected per day it would have led to a lot more distrust among them and with it a higher number of infected people in Colombia.

We also decided to analyse results of precautions taken in Colombia and the impact they had on the number of cases in the country, them being 33% effective in average, letting us know that people only cooperating a bit managed to impact in the containment.

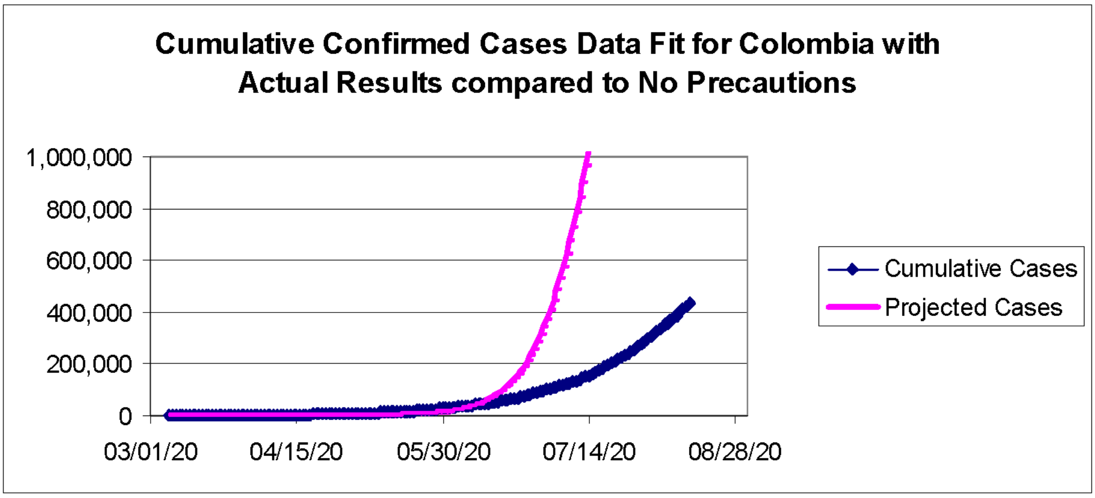


Figure 16: Cumulative Confirmed Cases with No Precautions Compared to the Actual Results

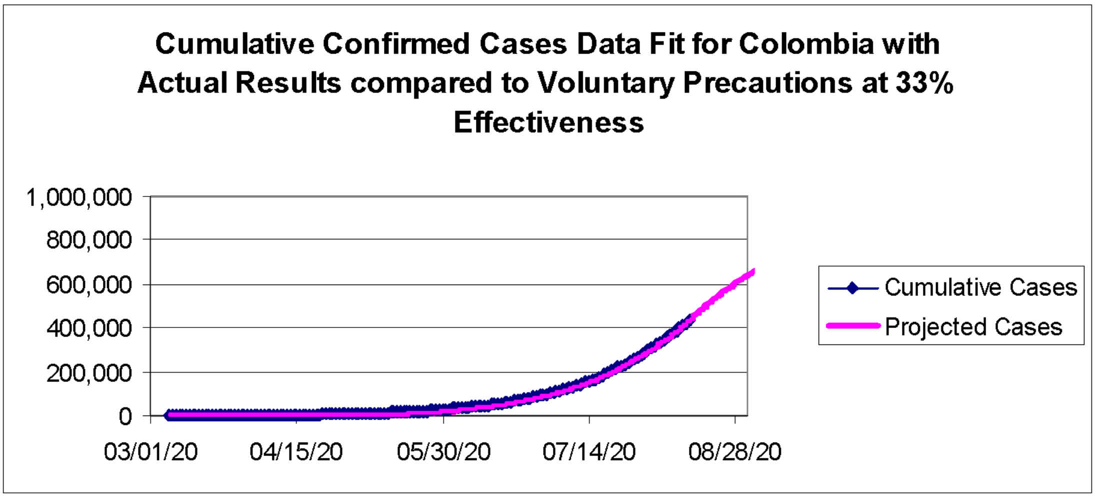


Figure 17: Comparison of Actual Results compared to Voluntary Precautions at 33% Effectiveness

If only voluntary precautions are taken, the cumulative confirmed cases are projected to increase from 433,805 on August 14, 2020 to about 1,750,000 by January 1, 2021 (see Figure 18).

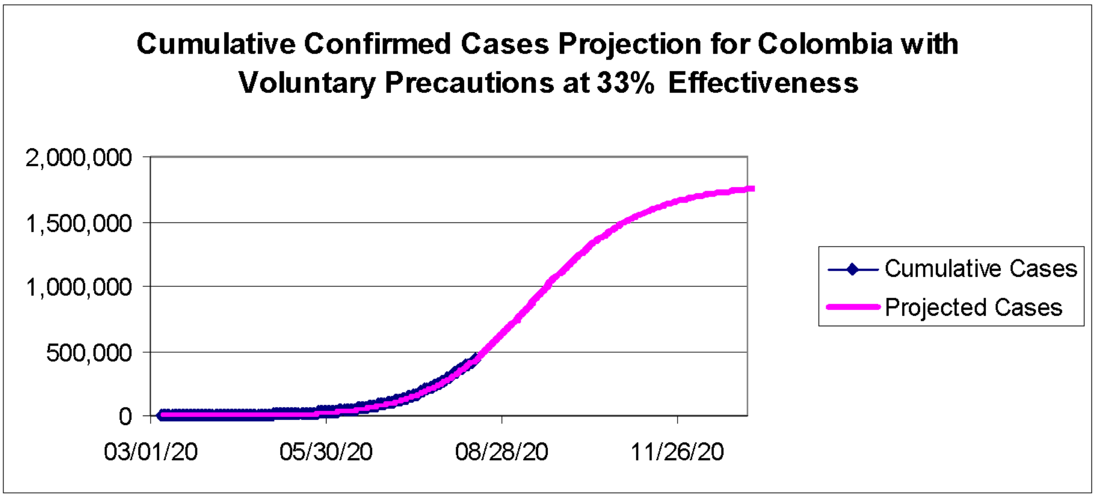


Figure 18: Projected Cumulative Cases with Voluntary Precautions at 33% Effectiveness

The daily confirmed cases are estimated to be almost at their peak as shown in Figure 19. So if the government takes no action, the situation is projected to start to get better anyway.

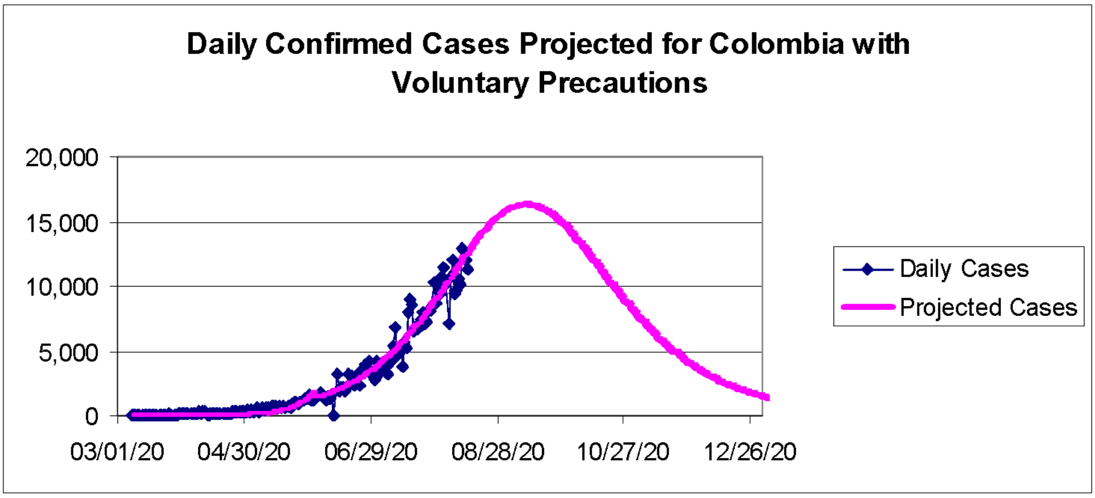


Figure 19: Daily Confirmed Cases Projected for Colombia with Voluntary Precautions

However, we assume that the government decides to establish regulations on August 15, 2020 and estimate the impact of these regulations assuming different levels of effectiveness (40%, 60%, and 80%) and different durations of the regulations (30 days, 45 days, and 60 days) (see Table 3). It is assumed that the population goes back to voluntary precautions at 33% effectiveness after the regulations are lifted. Figures 20 and 21 show the sensitivity analysis results graphically. The model projects that effective government regulations in place for a relatively long period of time could result in a reduced number of confirmed cases compared to relying on voluntary action only.

Table 3 Sensitivity Analysis on Government Regulations Effectiveness and Duration

Scenario	Precautions Effectiveness	Regulations Duration	Projected Confirmed Cases on January 1, 2021
0	33%	No regulations	1,750,000
1	40%	30 days	1,630,000
2	60%	30 days	1,300,000
3	80%	30 days	1,010,000
4	40%	45 days	1,580,000
5	60%	45 days	1,140,000
6	80%	45 days	825,000
7	40%	60 days	1,540,000
8	60%	60 days	1,030,000
9	80%	60 days	758,000

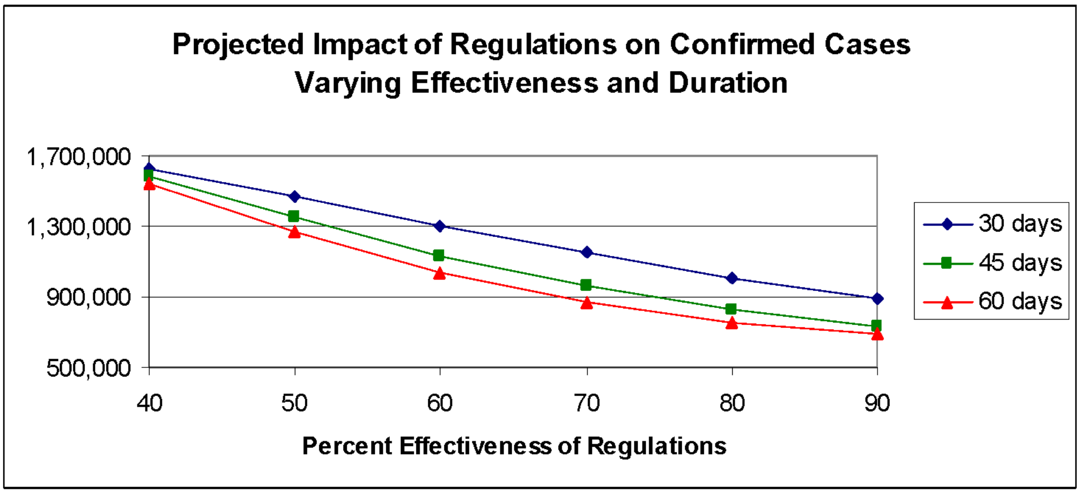


Figure 20: Impact of Regulations Varying Effectiveness and Duration

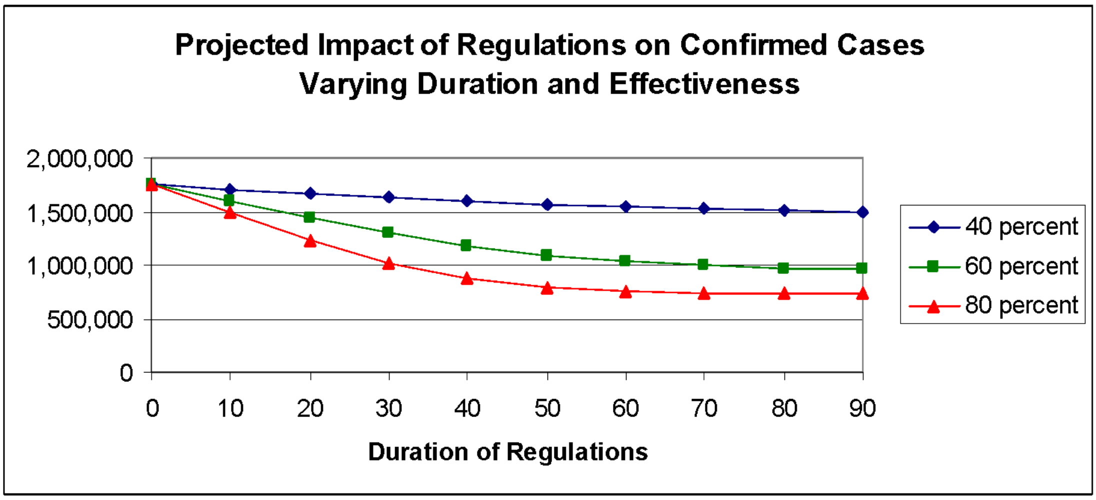


Figure 21: Impact of Regulations Varying Duration and Effectiveness

5. Discussion

We based our hole work on what Ostrom said in the year 2000, where he established that trust is gained by communicating information to the population, but not everything we communicate is going to be effective to increase the trust(Ostrom 1994, 2000), and that is what we focus on with our study.

We also based on a work developed by one of our authors(Jorge Andrick Parra), were he defined what a large-scale social dilemma is and what are their characteristics, which helped us define the pandemic as one, seen in figure 23.

Aspect/Definition	Small	Large-Scale
Communications	Face to face	Posible
Members	10	¿10
Group	Common interests	Diversity
Dynamic Complexity	Low	High
Cooperation Feedback	Perfect	Late

(Ostrom 2000; Markóczy 2003;
Parra Valencia 2010)

Figure 23: Large-Scale social dilemma characteristics.

Also, from the 1st of September Colombian government decided it was time for them to reopen the economy, based on the great results(less infected and peak reached) but that's not true. The real quantity of infected is unknown and government is just making less testing in order to find less infected, while also data obtained from the web: our world in data, shows Colombia has a 33% positivity rate, which means the crisis is not near to being controlled. Both data is shown in the figures 24 and 25.

Figure 24: Colombia positivity rate.

Figure 25: testing per thousand in Colombia.

Also taking into account our input with this investigation is that nobody has evaluated how trust and cooperation affect the development of a pandemic, we see convenient to support it with similar researches. First we have "Effects of the COVID-19 Pandemic and Nationwide Lockdown on Trust, Attitudes Toward Government, and Well-Being" work done in New Zealand, were the population was evaluated before and after lockdown was established in the country and results were very clear, trust affects how a pandemic develop in a country and the cooperation of the population is needed for a successful and both are affected by how decisions taken by the government have a successful impact on the crisis, for all the information above we conclude this is a very important investigation, which supports our work completely and helps us build conclusions, containment. Another important work is: "Social trust in the midst of pandemic crisis: Implications from COVID-19 of South Korea" study made in South Korea that analysed how giving proactive responses by different institutions during a crisis helps build up trust, information we can associate with Colombian institutions, and help us conclude that due to the lack of those types of responses Colombian people do not trust at all in them, leading to a worse crisis. We also analysed "A mathematical model reveals the influence of population heterogeneity on herd immunity to SARS-CoV-2" Work that establishes that depending on how strong actions taken to help in the containment of the virus, there is going to be a different outcome, and that is also a very important input that helps us a lot in the making of conclusions.

6. Conclusions

A System Dynamics model of the COVID-19 epidemic in Colombia was built to determine the level of effectiveness of regulated and voluntary precautions at limiting the spread of COVID-19 in ***Colombia.*** Also, the model was used to determine the effectiveness of efforts to protect the most vulnerable people and thereby reduce the number of further confirmed deaths.

An analysis of the time-series data from April, May and June demonstrated the regulated precautions have not been effective at limiting the spread of the virus. The results in July appear to show that any voluntary precautions have also been ineffective. Also, it appears that Colombia has not done enough to protect the most vulnerable people in the country and the death rate has not decreased sufficiently to limit the number of confirmed deaths.

The cause and effect nature of System Dynamics modeling and the quality of the data fit provide a high level of confidence in the ability of the model to project future values. ***The results of these projections imply that the spread of the virus will peak around early September as Colombia reaches herd immunity. COVID-19 will likely remain a serious problem in Colombia for the rest of 2020.***

We also conclude that:

- The pandemic is in fact a Large-Scale social dilemma, where people is between cooperating and not.
- Not communicating effectively to the population what's important for them to know affects the dynamic of the pandemic.

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