A Tentative Simulation Scheme of the Covid-19 Propagation to Help in Managing the First Responding Actions

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During the 1st phase of all major crises, responses are needed despite the lack of realistic data that can't be issued but from the field. Decision makers can't wait the arrival of real field collected data. However, they need rational support to make decisions. Rational support should be systematic and perform close—to-real simulations.
Considering the COVID-19 global crisis and specifically the French case, decision makers are presently, (March 2020), focusing on two sets of populations: the set of infected individuals and the set of deceased individuals.
Regarding the infected population set, decision makers should assess the capacity of the medical infrastructure to handle the infected individuals (partially or totally) by medical treatment and by isolation. Both medical treatment and isolation require adequate infrastructures and resources. The adequacy between the required infrastructure/resources and the existing ones should be assessed as best as one can and in an evolutive (dynamic) manner. Financial consequences of bad assessments may endanger the whole economy of the state.
Regarding deceased individuals, decision makers need preparing adequate public communication patterns including explanations and perspectives. All inadequate responses may engender serious social unsatisfaction and irrational panics whose political consequences may seriously impact on the governance effectiveness.
Simplified mathematical models demanding few input data are of special interest during the earlier phases of a crisis management. They require small amount of resources, give immediate 1st order insight of the crisis and are interactive self-learning beings. Simplified models are thus very appreciated by decision makers.

1. What major sets to be considered?

The proposed model considers only four sets of major interest, FIG.1: $E1$ (Healthy Population), $E2$ (Infected Population), $E3$ (Recovered Population) and $E0$ (Deceased Population).
The individuals belonging to $E1$ may catch the virus with a daily infection rate of $\lambda1$.
The individuals belonging to $E2$ may either recover with the daily recovery rate of ρ or decease with the daily death rate of ν. The recovery rate ρ is in some way a global parameter covering natural recovery and medically assisted one. While, the death rate ν covers all death cases effectively caused by COVID-19, wither identified as such or not.
The individuals belonging to $E3$ may either re-catch the virus but with a lower daily infection rate $\lambda2$, ($\lambda2 < \lambda1$) or join $E1$ at a daily rate of μ, as if they have never been infected.
The model does not distinguish between "detected infected individuals" and "non-detected infected ones". Neither, it does distinguish between symptomatic and asymptomatic infected individuals. It does neither distinguish between the deceased individuals counted by the medical institutions and those counted by the civil administration. It does not specifically identify the contribution of the medical actions: testing, detection, and clinical care, as well. The mentioned four sets are macro-sets.
This is the simplest graph of states one may conceive.

If the transition rates $(\lambda1, \lambda2, \mu, \nu, \rho)$ are all time constant, one may apply Markov Stochastic Process. It requires easy simulation tools and few resources.

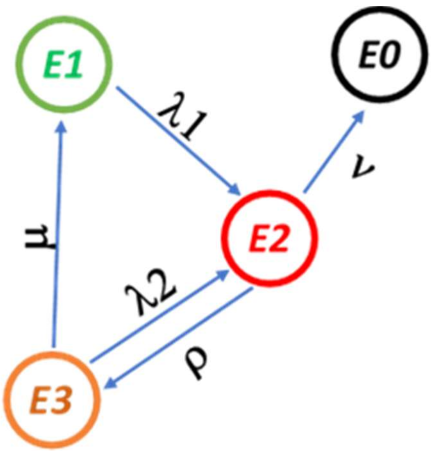

FIG.1
Graph states representation of the model

This work is undertaken on an independent-initiative base [2]. It does not reflect any institutional position regarding modelling & simulation tools that are exploited by the French official institutions concerned by the COVIDA-19 crisis management.

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2. What numerical data to put in?

We propose a simple model that demands limited amount of resources and exploits easy simulation tools. It is an evolutive and self-learning model. The real issue in any simulation model is the identification of the pertinent data to use. The proposed model requires 5 input data called the transition rates $(\lambda 1, \lambda 2, \mu, \nu, \rho)$. They are all measured in $d^{-1} capita^{-1}$.
In Table 1, we give the numerical values of the transition rates, the rationales justifying these values and a short assessment of the corresponding uncertainty that one may expect.
Each of the above-mentioned transition rates contains uncertainties. These uncertainties will certainly be reduced progressively thanks to the continuous data feedback measured during the real evolution of the epidemy on the ground. Thus, the robustness of the model progresses in parallel with the crises.
However, one most critical input data is the "outbreak date" of the epidemy in France.
On the 24th of February, a zero-contamination cases were reported in France by Le Monde[3]. On the 25th of February, some one hundred cases were identified between the 2nd and the 25th of February and reported by Le Mode[4]. In the absence for more details, we assume that **D-day is the <u>15th of February, 2020</u>**.

3. Numerical Results and Synthesis

At present in France, the decision makers are focusing on the two following sets: the set of infected individuals ($E1$) and the set of deceased individuals $E0$. In FIG.2, we show the estimated evolution profile of the number of the infected individuals over a period of 180 days, starting from the **<u>15th of February</u>**.
In Table 2, we give the estimated values at some instants of time for the following sets: the infected population, the recovered population, the deceased population and a death rate each 10 days.

For the 26th of March (D+40), the model estimates, Table 2, the total number of the infected individuals (identified or not) to be as high as 73 354 individuals, the total number of recovered individuals (symptomatic or asymptomatic) to be around 97 419, the total number of deceased individual as high as 5 850 and the estimated rate of death equal to 1 828 cases in 10 days. This is the highest estimated death rate over the investigated period of 100 days. It decreases right after, Table 2. A comparison can then be done with the official COVID-19 data site[5], noting that the data on the official site considers only confirmed cases counted by the medical institutions. Another important figure that may help in assessing the likelihood of the results is the death rate in France in normal conditions which is about 612 000 cases per year[6]. That means an average rate of ~17 000 death cases each 10 days. The estimated cumulated number of deceased persons by COVID-19 at D+40 is 5 850 cases, Table 2. It corresponds to an increment of 1 828 over 10 days. That represents an increase of 11% in the national rate of death each 10 days, in normal conditions. Such increase should be easily detectable in the civil administration records dealing with death declarations by March the 26th (D+40).

4. How much could the governmental restrictions improve the situation?

If we consider the two restrictions: the "social distance" and the "confinement". Let's assume it aims at reducing the number of each one's daily physical contacts by factor 6. It is to say, if you have 12 close physical contacts in your normal daily life, you should reduce them to only 2 distant physical contacts. So, I can suggest a daily infection rate $\lambda 1$ equal to $1.1 \times 10^{-5} (\lambda 1 = \frac{6.6 \times 10^{-5}}{6})$ per day per capita. Secondly, we also assume an immediate return to the state $E1$ after recovery ($E3$) thanks to the improvements in the clinical awareness and practices (gained in 40 day time) with no other considerations (drugs treatment or antivirus). Finally, we assume that the effect of the restrictions will appear within ~ 20 days after D+40 (26/03/20), i.e. around D+60 (15/04/20).

If we apply rigorously the restrictions, we notice a rapid decrease in the total number of the infected population ($E2$) starting from day 60 to attend the asymptotic limit of only 8 900 infected individuals after on day 120, all measured from D-day, FIG.3.

[3] Le Monde of 24/02/20. https://www.lemonde.fr/planete/article/2020/02/24/coronavirus-mesures-de-precaution-hausse-de-la-mobilisation-comment-la-france-se-prepare-a-une-possible-epidemie_6030677_3244.html

[4] Le Monde of 25/02/20. https://www.lemonde.fr/planete/article/2020/02/25/deux-nouveaux-cas-de-coronavirus-en-france_6030825_3244.html

[5] https://www.gouvernement.fr/info-coronavirus/carte-et-donnees

[6] INSEE report, « Bilan démographique 2019 », France. (https://www.insee.fr/fr/statistiques/4281618?sommaire=1912926)

Table 1: List of the macro-parameters, their values and rationales.

Para.	description	value	comments
$\lambda 1$	Daily rate of infection per capita (/d/c)	6.6×10^{-5}	High uncertainty. It is adjusted to be as close as possible to the available French data on 28/03/20.
ρ	Daily rate of recovery per capita (/d/c)	$\left(\frac{1}{T}\right)$	Low uncertainty. An incubation period of 14-21 days is generally admitted for confirmed infected individuals if they have no medical problems, well-fed, at rest and isolated. In addition, CDC Director Dr. Robert Redfield declared that as many as 25% of the infected remain asymptomatic.[7]. It is highly probable that asymptomatic have naturally higher resistance than others. It is likely they have the lowest incubation period. An approached Incubation time T is: $T = 75\% \times 21 + 25\% \times 14 = 17.5d$
ν	Daily rate of death per capita (/d/c)	$4\% \times \rho$	Low uncertainty. Dr R. Redfield declared that as many as 98% of the infected recover[8]. We considered that the deceased ratio is some 2% of the confirmed infected but under medical observation. This population is then symptomatic. In order to count for the death cases of the asymptomatic cases, as well, we considered an overall death ratio of 4% of both populations: symptomatic and asymptomatic.
$\lambda 2$	Daily rate of re-infection per capita (/d/c)	$\frac{\lambda 1}{2}$	Medium uncertainty. it Expresses the possibility of eventual increase in the immunity system resistance after the 1st infection. The figure is of low impact on the final numerical results.
μ	Daily rate of joining the initial set (/d/c)	$1/400$	High uncertainty. It expresses the absence of any immunity improvement. The immunity system losses the genetic signature of the virus after the 400 days from the 1st infection date or the virus has muted within this 400 day. (any figure higher than 365d can be used. One puts 400d). The figure is of low impact on the final numerical results.

Table 2: projection of COVID-19 progression for a population of 68M (starting at 15/02/20)

#	Date		Infected	recovered	Deceased	Deceased increment
0	0	15/02/20	0	0	0	0
1	+10	25/02/20	34 661	9 712	713	713
2	+20	06/03/20	54 829	32 832	2 232	1 519
3	+30	16/03/20	66 552	63 250	4 022	1 790
4	+40	26/03/20	73 354	97 419	5 850	1 828
5	+50	05/04/20	77 290	133 288	7 627	1 777
6	+60	15/04/20	79 556	169 676	9 325	1 698
7	+70	25/04/20	80 850	205 909	10 945	1 619
8	+80	05/05/20	81 578	241 608	12 494	1 549
9	+90	15/05/20	81 977	276 565	13 983	1 489
10	+100	25/05/20	82 186	310 670	15 420	1 437

[7] CDC Director Dr R. Redfield through a phone-interview with Sam Whitehead, the health reporter at WABE in Atlanta, on Monday 30 March 2020. https://www.npr.org/sections/health-shots/2020/03/31/824155179/cdc-director-on-models-for-the-months-to-come-this-virus-is-going-to-be-with-us?t=1585816492203

[8] CDC Director Dr R. Redfield through a phone-interview with Sam Whitehead on Monday 30 March 2020.

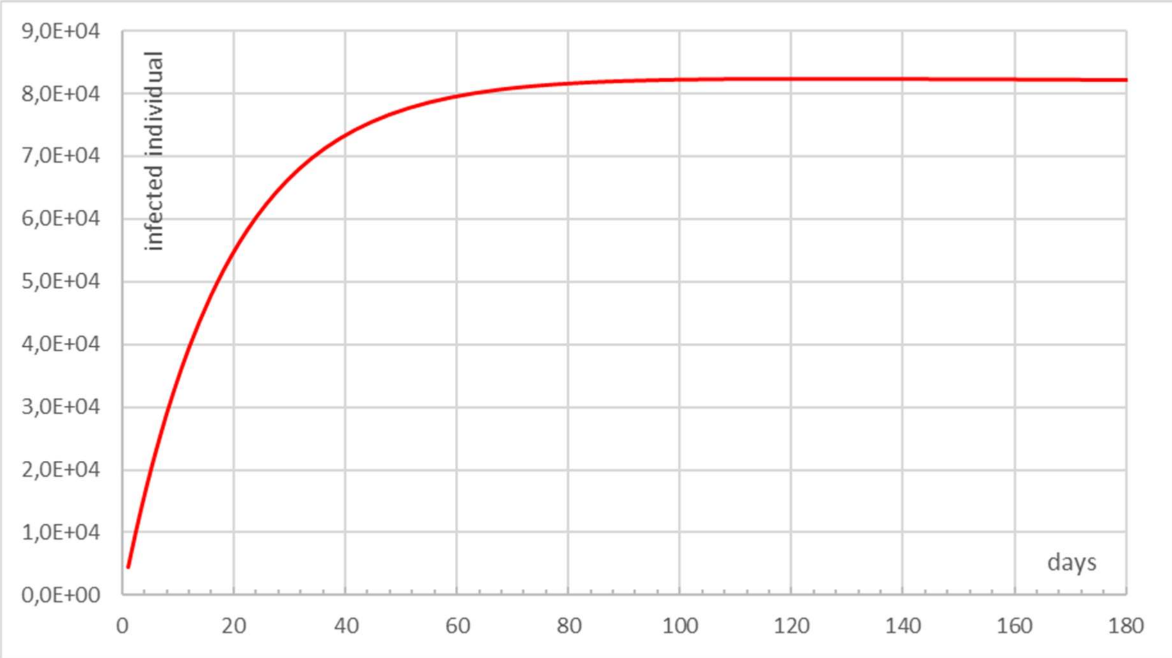

FIG.2
The evolution of the set of the “infected population”, (*E2*)
(no restrictions scenario)

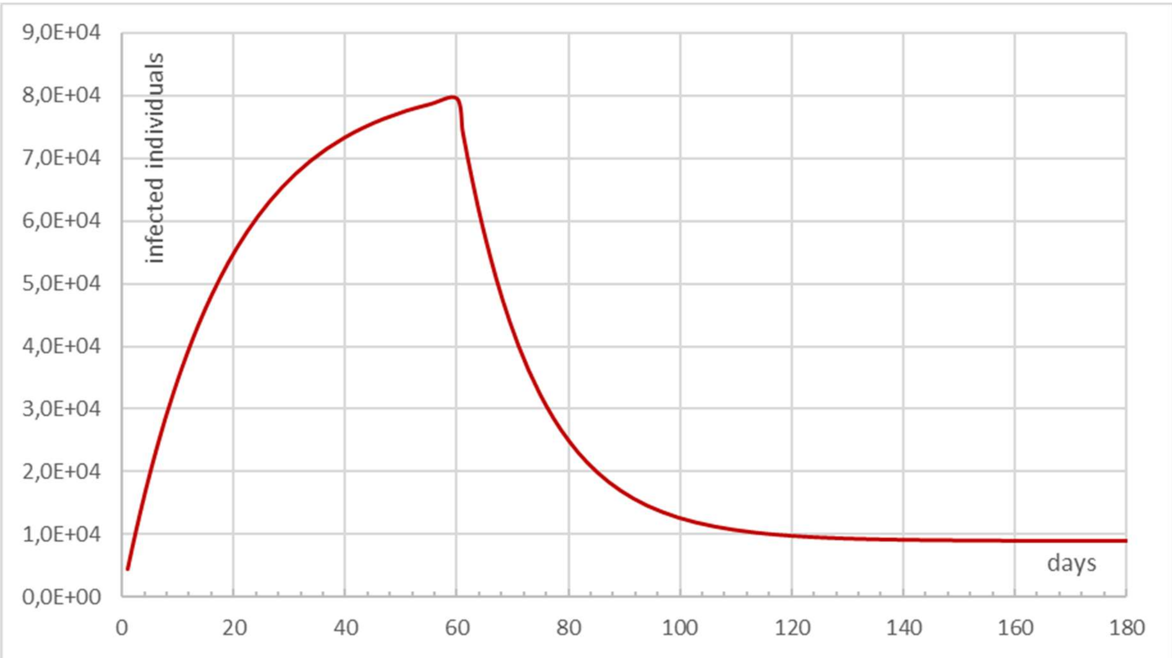

FIG.3
The evolution of the set of the “infected population”, (*E2*)
(with stay-at-home restrictions)