

# Dynamic Modelling and Live Prediction of COVID-19 Using SIR-D model.

On projection of COVID-19 Peak and using simple spreadsheets for Pune district and Maharashtra region.

Rajas Vijay Chavadekar (*Author*), 30<sup>th</sup> of April, 2020. updated 21st of July, 2020.

Sinhgad College of Engineering, Vadgaon, Pune, Maharashtra, India.

rvchavadekar@gmail.com

linkedin.com/in/rvchavadekar

**Abstract**—This research puts forth an approximate quantitative prediction of COVID-19 (coronavirus) counts i.e. affected, infected and dead population and suggestions on measures to be taken in Pune City district and The State of Maharashtra in coming months. The effects of lockdown and public mobility in the city and state are discussed regarding the above counts, the overall magnitude and time-wise progress of the pandemic. This document also provides some important suggestions to the bodies in execution as well as the individuals in the city. We have coarsely made an attempt as an individual to map the further cases and do the planning accordingly although there are various prestigious organizations working on this issue. The research is now updated the observations and made respective prayers considering the latest data. With the increasing COVID-19 counts, a separate spreadsheets are included for Pune District and Maharashtra state as well.

**Keywords**—pandemic, prediction, SIR-D epidemic model, mathematical modelling, COVID-19, Pune City, Maharashtra State.

## I. INTRODUCTION

With the outbreak of Coronavirus in Pune active since 9<sup>th</sup> of March, 2020, there has been a lot of strain on the health services, law enforcement, and the overall tolerance of people. This report provides a crude prediction and also a spreadsheet [1] which has SIR-D [2] epidemic dynamics implemented. The reason for applying this model was the available data [3][4][5] which showed the total, active, recovered and dead cases. The main motive of this analysis is to give analysis and suggestions to the bodies in execution about the peak of pandemic. The Peak for Pune District is expected around August mid, 2020 with approximately 70,000 reported active COVID-19 cases, ending around October mid, 2020. For State of Maharashtra peak is expected around September first week with approximately 4 lakh active cases, ending around November mid, 2020. The main question arises that why is it taking so long? Because we have ‘flattened’ the pandemic curve and flattening literally means postponing the peak but with lesser magnitude of active cases at the peak so the medical facilities do not get strained. The available beds in Pune are already full and many critical patients deprived of oxygen life support face immediate fatalities hence the Governing Bodies should focus on creating new accommodations with oxygen life support,

medicines, ambulance services and trained ward boys, nurses and volunteers as they play a crucial role in monitoring patients. We should also meet the increasing demand of oxygen and hence multiply oxygen production.

It is suggested to provide Ayurvedic immunity booster packages commonly and readily (if possible, door to door delivery) available to all citizens, doctors, hospital staff and importantly to the patients in isolation.

Many people confuse between the definition of peak and rise of pandemic. The pandemic is at its peak when the active cases become constant and gradually begin declining over a period of time and rise of pandemic is when there are highest number of affected individuals per day. For 12 days since 11<sup>th</sup> of July, we have seen a steep rise in active cases of Pune. This is because, the complete lockdown induces insecurity within citizens for essential services and crowding is observed due to restricted time window. Hence it is suggested to open all essential services for full working hours with restricted movement to avoid crowding such that there is a steady and controllable progression of pandemic.

It is observed that out of complete population hardly 2 to 3% people are the ‘reported’ affected COVID-19 cases. However out of rest 97 to 98% of population, many people may be already affected but will not report officially. We can understand this factor from New York where 4.5 lakh out of total population 19,440,500 [24] is infected so hardly 2.31% out of total population are ‘officially’ reported cases. In new version (1.2) of spreadsheet we have applied this factor thus giving more accurate projections.

**We have given live spreadsheets for Pune District and Maharashtra state that calculates prediction for any other city/locality by just putting in the actual values at respective dates in the red bordered inputs.**

## II. MOTIVATION

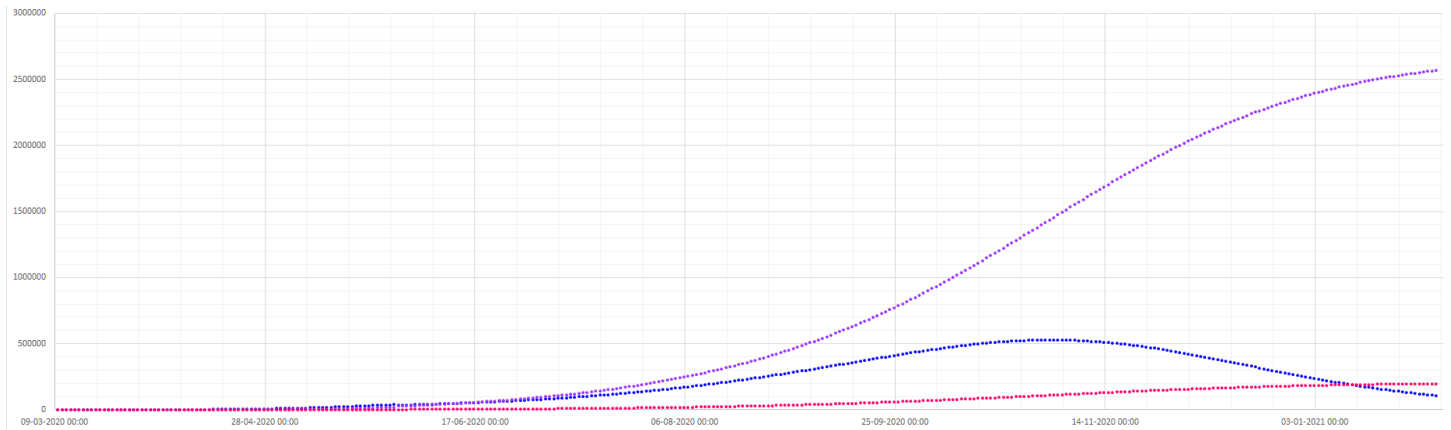
The main motivation of this research was to exactly study COVID-19 dynamics in order to frame further planning of all kinds of economic and social policies.

It was in August 2019 well before the outbreak, since my father Late Dr. Vijay Chavadekar left the world because of ILD (Interstitial Lung Disease). My father was critical on oxygen life support since two and a half years and after which we prepared for a bilateral lung transplant. He faced severe casualty while transporting for a lung transplant in ambulance itself after which he didn't open his eyes ever. It is our experience that the respiratory cases are extremely fragile which the medical teams are handling reluctantly.

I couldn't save my Father being potent in my skills but I earnestly don't want so many people to face similar conditions which is why I am deeply studying this pandemic and is trying to put my honest efforts in order to alert and update all the bodies in execution on how to maximize the recoveries. Because I and my family have handled all the economic and clinical crisis and we know what it is to lose the most precious and we know what is the pain that these thousands of families are facing who have really lost their loved ones in the wave of this virus.

## III. THE PREDICTION, SUGESTED ACTIONS AND IMMEDIATE PRAYERS

This section describes about the approximate future progress of the virus in the metropolitan and tries to give some suggestions to the bodies in execution and the readers of this document. The total population 94.29 lakhs [27] was taken for Pune and 12,48,62,220 for Maharashtra from [9]. But applying the reported percentage of New York to Maharashtra, total  $12,48,62,220 \times 2.31\% = 28,90,255$  will be officially reported till the end of pandemic. In same analogy we apply the reported percentage of Queens to Pune considering its area population density. So, for Pune District total  $94,29,000 \times 3.07\% = 2,89,625$  will be officially reported till the end of pandemic. In this version we have applied this criterion over the population of Pune and Maharashtra after which the accuracy has largely increased (reflected in updated version 1.2 published).



**Figure 1: The Progression of COVID counts for Maharashtra, blue = infected, purple = recovered, red = deaths.**

**TABLE I. PREDICTED COUNTS OF COVID-19 FOR MAHARASHTRA TILL 26<sup>TH</sup> OF JUNE 2020**

Date	Predicted COVID-19 Counts in Maharashtra		
	Total Affected	Recovered	Deaths
22/07/2020	337875	187128	12691
23/07/2020	347722	192871	12983
24/07/2020	357825	204835	13284
25/07/2020	368187	211062	13593
26/07/2020	378815	217459	13911

<sup>a</sup>. The previous data was provided by [4][5] and predicted figures can have  $\pm 10\%$  error

**TABLE II. PREDICTED COUNTS OF COVID-19 FOR PUNE DIST. TILL 26<sup>TH</sup> OF JUNE 2020**

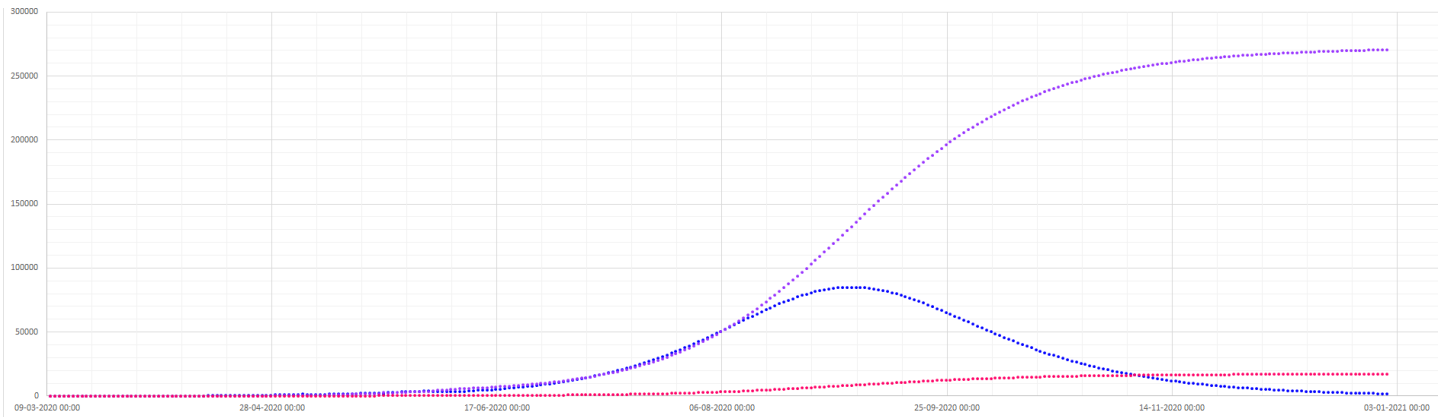
Date	Predicted COVID-19 Counts in Pune		
	Total Affected	Recovered	Deaths
22/07/2020	62706	22257	1509
23/07/2020	65808	23081	1563
24/07/2020	69052	23952	1620
25/07/2020	72441	24870	1681
26/07/2020	75975	25839	1745

<sup>b</sup>. The previous data was provided by [12] and predicted figures can have  $\pm 10\%$  error

### A. Restriction Strategy in the race of Economy vs Health

We definitely understand the economic crunch and loss of revenue which is very dependent on the mobility of individuals and their transactions. Which is why a stepwise restriction is suggested.

In the last 12 days from 11<sup>th</sup> of July, 2020, we have seen a steep rise in active cases of Pune. This is because, the complete lockdown induces insecurity within citizens for essential services and crowding is observed due to restricted time window. Hence it is suggested to open all essential services for full working hours with restricted movement to avoid crowding such that there is a steady and controllable progression of pandemic. Hence sudden application or lifting of strict lockdown may highly dabble the pandemic from the proposed model in negative manner. Due to sudden ramp up



**Figure 2: The Progression of COVID counts for Pune District (same legend as Figure 1.)**

of infected population, the existing medical facilities can get overstrained and probably the situations may get out of control.

#### *B. Health Parameters, Handling of Oxygen and Life Support System*

The handling of Oxygen life support is highly critical while treating the active patients. For such cases 24-hour oxygen therapy is suggested. It is medically observed that, human body requires high oxygen (double or triple the normal) if the patient is having lunch or dinner or while at toilet. In such situations expert handling and high oxygen supply is necessary so that we can reduce major fatalities caused due to lack of oxygen while doing such activities.

The role of trained ward boys, nurses and volunteers in the isolation centers and hospitals is very crucial in handling of any kind of emergencies. They should be specially trained to handle such situations. There are many deaths reported till now which are due to the lack of Oxygen, mixing of active COVID-19 patients with suspected isolated patients. Corrective measures regarding this are highly suggested.

It is very true that there are still not adequate accommodation and emergency support available for the COVID-19 Patients specially in Pune. Even critical patients on oxygen in ambulances are struggling to get a bed in hospital.

However, it is very appreciable that the multinational IT and automobile companies in Pune like Tech Mahindra [16] has developed reasonable ventilators, Wipro [17], and Mercedes Benz [18] have developed their facilities with full-fledged COVID-19 isolation units that can accommodate the critical patients in thousands. Also, the SKN hospital at Narhe, Pune [19] has a capacity of accommodating 500 patients. The Pune Civic hospital has made considerable installations for handling COVID-19 patients [20].

But whenever we setup a facility or isolation beds for COVID-19 patients, we have to setup all other facilities like

their timely and hygienic food, sanitation, their medicine, one must not be in proximity of other patient's infection, and a trained, immune and dedicated staff to handle any kind of emergency one has.

The overall production of Oxygen must be increased to meet the demand of increasing critical patients as it is observed that there are many deaths due to lack of Oxygen life support to emergencies.

The new findings of COVID-19 say that this virus highly mutates in response to a person's immunity. If a person is immune to a particular kind of mutation, then antibodies for such immunity lasts for approximately 6 months. The people of Indian origin have high immune response due to the significant presence of the HLA genes [14]. However, Indians having this natural advantage above a certain threshold of infection can fight no more against the virus.

#### *C. Suggested Role and Policies of Industries, Offices and Commercial Activities*

It has been observed that the current structures of the IT workplaces have poor ventilation, air conditioning and hygiene practices and external air exchange. This will not only promote the absolute spread of infection but also decrease the overall immunity of the employees. Frequent air exchange and better ventilator is highly suggested in these cases and hereafter. It is therefore suggested post lockdown to change the ventilation architecture if possible.

If we have to keep the human resources intact, then we have to actively participate in the planning of further strategies like levying tasks on work from home basis in accordance with the predictions which in turn we will have to make by tedious data analysis and which is why we would encourage such companies to draw certain conclusions and respond to the government and bodies in execution rather than blindly following the instructions. The efforts of covid19india community on github [28] are really appreciated for creating a

valid source of data and very intuitive portal with many features. However, for now it is highly suggested to put only the skeletal human resources in immediate mobility on site and patiently wait for the peak to pass. After the situation calms down considerably, and if Industries in Pune are able to maintain such disciplines, it may as well attract considerable potential investments in near future.

The nature of virus is such that an infected individual is asymptomatic for the incubation period and causes acute lung fibrosis after the lungs are completely infected and immediately need high oxygen support or ventilation. Lack of such support may lead to immediate fatal by cardiac arrest due to lack of oxygen levels in body due to lung fibrosis. It is therefore suggested to keep a pulse oximeter machine, a portable oxygen concentrator machine, a portable ventilator kit and a person who has knowledge of giving CPR. Frequent monitoring of not only temperature but parameters like blood saturation and heart rate is highly suggested to keep track of such probable cases for the employees. One must take this setup as seriously as a fire extinguisher kit installed in company. This is suggested not only for big Industries but also for all small- and large-scale industries who are resuming their work.

The employees must be tested before resuming to work. Basically, it is suggested to take two following tests mandatorily taken before putting any human resource at work i.e. immune-profile (multiple tests consisting of CBC, Random Sugar, IgA, IgG, and IgM tests) or ANA (antibody) test and COVID-19 test. The immuno-profile test should show up with considerable count of antibodies required to resist this infection and secondly that individual oneself should not be infectious which is given by COVID-19 test.

#### *D. Distribution of Ayurvedic immuno-booster packages or kits.*

According to the advisory of Ministry of AYUSH [21]. As well as it is evident from many instances that Ayurveda is effective in prevention. Many people are taking homemade medicines and remedies such as basil – pepper – ginger tea, medicinal steaming and supplementary vitamins at their own pace.

The immunity promoting packages should be made commonly and readily (if possible, door to door delivery) available to all citizens, doctors, hospital staff and importantly to the patients in isolation. Either paid or if possible free of cost. It is therefore our request to the Ministry of AYUSH and volunteering organizations to come into action in this regard which might reduce critical COVID-19 cases in initial stages itself.

#### *E. Rectifying the problem of sanitation disposal in drinkable water bodies: Khadakwasla Dam backwaters in Pune*

It is observed that some of the villages and settlements near the catchment area of Khadakwasla Dam backwaters in Pune are disposing their sanitation in the backwaters itself, which is supposed to be classified as drinking water [22]. Rather it is in general observed, not only in Maharashtra but in nearly all of the nation where sewage is disposed in drinking water bodies.

It is evident that even in Paris, France, their sanitation being entirely disconnected found traces of virus in their drinking water. The considerable count of COVID-19 in their sewage water pointed to their early warning system [23].

There has been considerable amount of active COVID-19 cases in the nearby villages who have been found to dispose their wastes in the water body itself [23]. These villages themselves fetch the same contaminated backwater thus causing a contaminated feedback to amplify not only COVID-19 but any kind of infection further. The same water is supplied to the entire Pune City. Strict corrective measures are suggested in order to curb and terminate any kind of contaminations, by the Government and local bodies in execution.

#### *F. Comparative analysis, best and worst case of coronavirus – Thailand and New York, and where Pune lies*

Since 8<sup>th</sup> of April, Thailand has observed a huge drop in COVID-19 active cases from start of outbreak on 15<sup>th</sup> of February. Till now at peak it had merely 1,451 active cases and only 58 are dead as of June 22 [10]. Due to strict restrictions, it seems that they have won the battle but they still consider the chances of second wave of outbreak. However, they are planning to lift things back to normal.

On June 30 New York had maximum active cases i.e. 2,96,232 cases and has passed the peak reducing active cases to 151976 as on 21<sup>st</sup> of July, 2020 [10].

One point to note that Thailand has dropped its counts by strict lockdown at initial stages itself and curtailed its spread. In contrast New York let develop its herd immunity over virus and conquered the battle. Considering New York, Maharashtra is speedily progressing towards the peak and in Pune, community spread has started. So we have no other option but to softly develop such herd immunity to conquer this virus.

### **IV. UPDATED ANALYSIS OF PREDICTED DYNAMICS V/S OBSERVED STATISTICS**

#### *A. Observations of previous 36 days for Maharashtra as of predictions done on 11<sup>th</sup> of June.*

The pandemic curve was fitted based on the parameters aggregated from 2<sup>nd</sup> of June to 11<sup>th</sup> of June, 2020. Due to the





individuals which seemed to reduce the daily new cases appreciably from 23<sup>rd</sup> of June to 14<sup>th</sup> of July (**annotation 1**). Also, from (**annotation 2 and 3**) we observe good recoveries and lesser active cases.

After declaration of lockdown on 11<sup>th</sup> of July there was a huge chaos observed on 12<sup>th</sup> and 13<sup>th</sup> of July. One point to note that there are 4% more active cases than predicted (**annotation 5**) and also there are 30% more active cases than predicted (**annotation 6**). As well there are 20% less recoveries than expected. This is because before applying lockdown individuals were permitted to take the essential services from 8 am to 12 pm. This small window of mobility causes people to rush to essential services which abruptly contributes to the multiplication of virus. After an incubation period of 5 days, exactly during which strict lockdown was

adverse effects of complete lockdown. However, death rate is pretty low [5] (**annotation 4**).

## V. ASSUMPTIONS AND DISCLAIMERS

### A. Source of data

As given in references [3][4][5], the data was taken from official portals of Government of Maharashtra. The collective data was found at [3] with previous records before lockdown since 9<sup>th</sup> of March 2020, and from [12] for Pune. But it is most important point to consider that how many tests are actually being carried out. Due to lack of testing the predicted data may seem overestimated at some instances. As 97% cases are asymptomatic or unreported i.e. they may not show symptoms but are still infectious and have ability to spread it further. It can happen that such population may not be tested and directly

time		N-S (total suspected)				I (infected or active cases)				R (Recovered)				D (dead)				curve parameters						flags					
time		act		pred if Inul	%error	act		pred if Inul	%error	act		pred if Inul	%error	act		pred if Inul	%error	a	b	c	act	con	act	con	act	con	null?	edit	
Δ	t	Δ	act	pred if Inul	%error	Δ	act	pred if Inul	%error	Δ	act	pred if Inul	%error	Δ	act	pred if Inul	%error	act	con	act	con	act	con	act	con	act	con	null?	edit
1	10-06-2020 18:00	333	10406	10406		140	3871	3871		182	6087	6087		11	448	448											FALSE		
1	11-06-2020 18:00	476	10882	10882		352	4223	4223		121	6208	6208		3	451	451		0.1144	c	0.0287	c	0.0007	c	FALSE					
1	12-06-2020 18:00	399	11281	11281		217	4440	4440		171	6379	6379		11	462	462		0.0913	c	0.0385	c	0.0025	c	FALSE					
1	13-06-2020 18:00	441	11722	11722		242	4682	4682		188	6567	6567		11	473	473		0.0958	c	0.0402	c	0.0023	c	FALSE					
1	14-06-2020 18:00	462	12184	12184		267	4949	4949		183	6750	6750		12	485	485		0.095	c	0.037	c	0.0024	c	FALSE					
1	15-06-2020 18:00	235	12419	12419		-308	4641	4641		529	7279	7279		14	499	499		0.0515	c	0.114	c	0.003	c	FALSE					
1	16-06-2020 18:00	469	12888	12888		446	5087	5087		14	7293	7293		9	508	508		0.0939	c	0.0028	c	0.0018	c	FALSE					
1	17-06-2020 18:00	362	13250	13250		223	5310	5310		117	7410	7410		22	530	530		0.0695	c	0.022	c	0.0041	c	FALSE					
1	18-06-2020 18:00	750	14000	14000		558	5868	5868		175	7585	7585		17	547	547		0.1305	c	0.0298	c	0.0029	c	FALSE					
1	19-06-2020 18:00	561	14704	14561	-0.982%	305	6118	6173	0.891%	241	8020	7826	-2.479%	15	566	562	-0.712%									c	TRUE	p	
1	20-06-2020 18:00	590	15286	15151	-0.891%	320	6375	6493	1.817%	254	8324	8080	-3.020%	16	587	578	-1.557%									c	TRUE	p	
1	21-06-2020 18:00	620	15881	15771	-0.697%	336	6658	6828	2.490%	267	8622	8347	-3.255%	17	601	595	-1.008%									c	TRUE	p	
1	22-06-2020 18:00	651	16474	16422	-0.317%	352	7071	7181	1.532%	281	8791	8628	-1.889%	18	612	613	0.163%									c	TRUE	p	
1	23-06-2020 18:00	684	16907	17105	1.158%	370	7141	7550	5.417%	295	9142	8924	-2.443%	19	624	632	1.266%									c	TRUE	p	
1	24-06-2020 18:00	718	17445	17823	2.121%	388	7401	7938	6.765%	310	9407	9234	-1.874%	20	637	651	2.151%									c	TRUE	p	
1	25-06-2020 18:00	753	18015	18577	3.025%	406	7650	8344	8.317%	326	9706	9560	-1.527%	21	659	672	1.935%									c	TRUE	p	
1	26-06-2020 18:00	791	19031	19367	1.735%	426	8331	8770	5.006%	343	10025	9903	-1.232%	22	675	694	2.738%									c	TRUE	p	
1	27-06-2020 18:00	830	19761	20197	2.159%	447	8732	9217	5.262%	360	10335	10264	-0.692%	23	694	716	3.073%									c	TRUE	p	
1	28-06-2020 18:00	871	20870	21068	0.940%	468	9448	9685	2.447%	379	10708	10643	-0.611%	24	714	740	3.514%									c	TRUE	p	
1	29-06-2020 18:00	913	21303	21981	3.084%	490	9620	10175	5.455%	398	10943	11041	-0.888%	25	740	766	3.394%									c	TRUE	p	
1	30-06-2020 18:00	957	22327	22938	2.664%	513	10305	10688	3.583%	418	11270	11459	-1.649%	26	752	792	5.051%									c	TRUE	p	
1	01-07-2020 18:00	1004	23317	23942	2.610%	537	10989	11225	2.102%	439	11545	11898	-2.967%	28	783	820	4.512%									c	TRUE	p	
1	02-07-2020 18:00	1052	24432	24994	2.249%	562	11640	11786	1.239%	461	11985	12359	-3.026%	29	807	849	4.947%									c	TRUE	p	
1	03-07-2020 18:00	1102	25454	26096	2.460%	587	12410	12374	-0.291%	484	12218	12843	-4.866%	31	826	880	6.136%									c	TRUE	p	
1	04-07-2020 18:00	1154	26956	27250	1.079%	614	13051	12988	-0.485%	508	13064	13350	-2.142%	32	841	912	7.785%									c	TRUE	p	
1	05-07-2020 18:00	1209	28142	28459	1.114%	642	13864	13630	-1.717%	533	13406	13884	-3.443%	34	872	945	7.725%									c	TRUE	p	
1	06-07-2020 18:00	1265	28966	29723	2.547%	670	14106	14300	1.357%	559	13971	14443	-3.268%	35	889	981	9.378%									c	TRUE	p	
1	07-07-2020 18:00	1324	30131	31047	2.950%	700	14892	15000	0.720%	587	14313	15030	-4.770%	37	926	1018	9.037%									c	TRUE	p	
1	08-07-2020 18:00	1384	31704	32431	2.242%	730	15932	15730	-1.284%	615	14810	15645	-5.337%	39	962	1057	9.888%									c	TRUE	p	
1	09-07-2020 18:00	1447	33394	33879	1.432%	762	17226	16491	-4.457%	645	15179	16290	-6.820%	41	989	1098	9.927%									c	TRUE	p	
1	10-07-2020 18:00	1513	35232	35391	0.449%	794	18680	17285	-8.071%	676	15526	16966	-8.488%	43	1026	1140	10.000%									c	TRUE	p	
1	11-07-2020 18:00	1580	37356	36971	-1.041%	827	20280	18112	-11.970%	708	16016	17674	-9.381%	45	1060	1185	10.549%									c	TRUE	p	
1	12-07-2020 18:00	1650	39125	38621	-1.305%	861	21601	18973	-13.851%	742	16427	18416	-10.800%	47	1097	1232	10.958%									c	TRUE	p	
1	13-07-2020 18:00	1722	40180	40343	0.404%	896	22196	19868	-11.717%	777	16857	19193	-12.171%	49	1127	1281	12.022%									c	TRUE	p	
1	14-07-2020 18:00	1796	42092	42139	0.112%	931	23738	20799	-14.130%	813	17202	20007	-14.020%	51	1152	1333	15.578%									c	TRUE	p	
1	15-07-2020 18:00	1873	44202	44011	-0.434%	967	25510	21767	-17.196%	851	17492	20858	-16.138%	54	1200	1386	13.420%									c	TRUE	p	
1	16-07-2020 18:00	1951	46668	45963	-1.534%	1004	27389	22771	-20.280%	891	18042	21749	-17.044%	56	1237	1443	14.276%									c	TRUE	p	
1	17-07-2020 18:00	2032	49037	47995	-2.171%	1042	29583	23813	-24.230%	931	18172	22680	-19.877%	59	1282	1502	14.647%									c	TRUE	p	
1	18-07-2020 18:00	2115	51575	50110	-2.924%	1080	31380	24893	-26.060%	974	18881	23654	-20.178%	62	1314	1563	15.931%									c	TRUE	p	
1	19-07-2020 18:00	2200	54624	52310	-4.424%	1118	33748	26011	-39.745%	1017	19517	24671	-20.891%	64	1359	1628	16.523%									c	TRUE	p	
1	20-07-2020 18:00	2287		54597		1157		27168		1063		25734		67		1695										c	TRUE		
1	21-07-2020 18:00	2375		56972		1196		28364		1109		26843		70		1765										c	TRUE		
1	22-07-2020 18:00	2466		59438		1235		29599		1158		28001		73		1838										c	TRUE		
1	23-07-2020 18:00	2558		61996		1274		30873		1207		29208		76		1915										c	TRUE		
1	24-07-2020 18:00	2651		64646		1312		32185		1259		30467		80		1994										c	TRUE		

Figure 4: Observations v/s Predictions on previous 27 days with labelled annotations for Pune District.

applied, suddenly over 2,000 new cases aroused after which for 5 days after daily over 2,300 new cases are rising.

Due to abrupt increase of active cases since previous 6 days, the recovery rate has drastically reduced from 58.6% on 11<sup>th</sup> of June to 35.9% on 20<sup>th</sup> of June [5]. There are 20% less recoveries than the model (**annotation 7**). Thus, we see

move to the recovered compartment after the incubation period i.e. when they have developed their immunity to do so. Such individuals may not come in actual counting and bypass our model. But this process can occur without hindrance only in slow restricted mobility of people to develop Herd immunity. Such herd immunity is an important factor that can

safely drive the population through this outbreak safely without any strain on the infrastructure.

### B. Accuracy

The predictions made in this model are accurate with  $\pm 10\%$  errors for next 15 days. The model for Maharashtra here is showing 9.06% RMSE for previous 32 days and for Pune, 5.21% RMSE (Root Mean Square Error) for previous 22 days. The accuracy further cannot be guaranteed as errors build up after differentially aggregating the model with a greater number of rows. With given data [3][4][5] under consideration, the curve fitting considers that the parameters of the model [2]. The model gives slightly volatile predictions as minute change in the curve parameters due to recent actions of the individuals or medical response on the active cases to be recovered can cause a huge deviation in predicted values. The prediction can be counter checked on [3][4][5]. Moreover, the recovered counts depend on many factors such as the change in the criteria of giving discharge from hospital as well the infected counts can vary from the model because of change in mobility of individuals, mutations of virus, temperature and climate, etc.

### C. Regarding the updates of the spreadsheet

**We have attached a live spreadsheet which gives the prediction accordingly. This spreadsheet can also calculate the predictions of any other city/locality by changing the input data.** As said previously that the model is highly volatile, and with incoming data, we may change the prediction model to advanced versions [2][7] which may as well drastically change the magnitude and time of predicted values. The updates of the same spreadsheet will be maintained on the site [1].

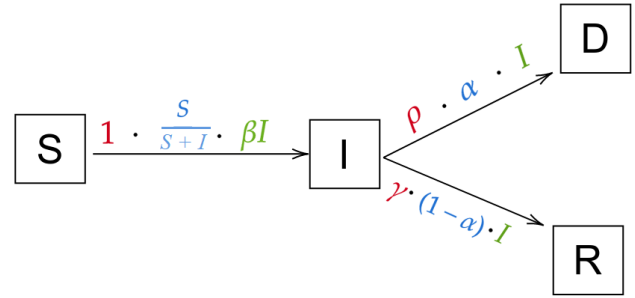
The spreadsheets from version 1.2 and so on do not have a separate lockdown column as that was for version 1.1. and 1.0. Each of the count of spreadsheet i.e. Affected, Infected, Recovered and Dead have an extra column for % error which activate when you analyze previous counts w.r.t predictions made before. More negative the error is (appears to be reddish cell), that count shows unfavorable deviation i.e. when the affected count is greater than predicted affected count on that day, it will show negative error and positive error (appears to be greenish cell) in opposite case, similar for death count. If actual recoveries are greater than expected then it will show positive error indicating improvement in recovery rate else in opposite case, we will get negative error which is a bad sign. When the error is closer to zero the cell appears to be yellow.

## VI. BASIS OF PREDICTION - THE SIR MODEL WITH FATALITIES

SIR, standing for Susceptible, Infected and Removed, modeling infectious diseases is as important as it has been in 1760, when Daniel Bernoulli presented a solution to his mathematical model on smallpox. It was however not until 20th century that mathematical models became a recognized tool to study the causes and effects of epidemics. In 1927, Kermack and McKendrick introduced their SIR-model based

on the idea of grouping the population into susceptible, infected, and removed. The model assumes a constant total population and an interaction between the groups determined by the disease transmission and removal rates. Although the removed represent in some models the vaccinated individuals, it can also be used to transform a time dependent population size into a constant population. In the latter case, the total number of contacts that a susceptible individual could get in contact with, is not the individuals of all three groups but  $S + I$  [6]. However, the Removed compartment contains both the recovered and death cases. We will derive these compartments as suggested in [2]. We will not actually solve this model analytically as their solutions are relatively complex and deriving the solution may require the reader to be proficient in solving the system of differential equations. But still if the reader is curious enough, one can refer [6]. We will try to fit an approximate curve formally known as state space fitting. In our case we will be using simple spreadsheet calculations to numerically solve by a variant of Euclid's method so that every reader can actually work with this model in their computers without installing any special software or programs like JRE, Python or other simulation runtimes.

### A. The Model



**Figure 5: The SIR transitions with dead compartment. [2]**

Every transition of the state is represented by three factors - The *rate*(red) describes how long the transition takes, the *population*(green) is the group of individuals that this transition applies to, and the *probability*(blue) is the probability of the transition taking place for an individual [2]. Where  $\beta$  is expected amount of people an infected person infects per day,  $\gamma$  is the proportion of infected recovering per day,  $\rho$  is rate at which people die ( $= 1/\text{days from infected until death}$ ) and  $\alpha$  is the fatality rate.

We investigate a susceptible-infected-removed (SIR) model proposed by Norman Bailey in of the form. The differential system [6] for our model with dead compartment becomes,

$$\frac{dS}{dt} = -\beta \frac{IS}{I+S} \quad (1)$$

$$\frac{dI}{dt} = \beta \frac{IS}{I+S} - (1-\alpha)\rho I - \alpha\rho I \quad (2)$$

$$\frac{dR}{dt} = (1-\alpha)\rho I \quad (3)$$

$$\frac{dD}{dt} = \alpha \rho I \quad (4)$$

For our computation purposes, resolution of parameters  $\alpha$ ,  $\beta$ ,  $\gamma$  and  $\rho$  is pretty tedious in the above forms and may as well lead to larger error in prediction. We need to derive simpler parameters of this ODE system to enable easy calculations. Let us define  $a$ ,  $b$  and  $c$  as,

$$a = \beta \quad (5)$$

$$b = (1 - \alpha)\gamma \quad (6)$$

$$c = \alpha \rho \quad (7)$$

Also, it must be noted that,

$$S + I + R + D = N \quad (8)$$

is constant, where  $N$  is constant. Furthermore, we do not have the Susceptible count, instead we have affected count  $A$  with us as sum of Infected, Recovered and Death population so,

$$A = I + R + D = N - S \quad (9)$$

Then our differential system becomes,

$$A = I + R + D \quad (10)$$

$$\frac{dI}{dt} = \left( a \frac{N - A}{I + N - A} - b - c \right) I \quad (11)$$

$$\frac{dR}{dt} = bI \quad (12)$$

$$\frac{dD}{dt} = cI \quad (13)$$

The parameters  $a$ ,  $b$ , and  $c$  can be the functions of time like  $a(t)$ ,  $b(t)$  and  $c(t)$  as the clinical responses and other factors like mobility and reproduction number can vary with time. Considering this, the curious readers can see the solution to this system of linear differential system with recovered and dead called as removed compartment  $R$ . the recovered and the dead both are proportional to the removed population  $R$  (here only), with this we have the solution from [6],

$$A = N - (N - A_0) \exp \left\{ - \frac{I_0}{N - A_0} \int_{t_0}^t \frac{a(s)}{\frac{I_0}{N - A_0} + e^{\int_{t_0}^s (b-a)(\tau) d\tau}} ds \right\} \quad (14)$$

$$I = I_0 \exp \left\{ \int_{t_0}^t \left[ \frac{a(s)}{1 + \frac{I_0}{N - A_0} e^{\int_{t_0}^s (a-b)(\tau) d\tau}} - b(s) \right] ds \right\} \quad (15)$$

$$R = N - \left( N - A_0 + I_0 e^{\int_{t_0}^t (a-b)(s) ds} \right) \exp \left\{ - \frac{I_0}{N - A_0} \int_{t_0}^t \frac{a(s)}{1 + \frac{I_0}{N - A_0} e^{\int_{t_0}^s (b-a)(\tau) d\tau}} ds \right\} \quad (16)$$

Where  $I_0$  and  $A_0$  are initial (at  $t = t_0$ ) number of affected and infected number of individuals. Being very impractical for their application we have to numerically solve this system.

### B. Parameters Estimation and Tuning

To resolve our newly derived parameters  $a$ ,  $b$  and  $c$ ,

$$b = \frac{1}{I} \frac{dR}{dt} \quad (17)$$

$$c = \frac{1}{I} \frac{dD}{dt} \quad (18)$$

Now plugging in (17) and (18) in (11), we have,

$$\begin{aligned} \frac{dI}{dt} + \frac{dR}{dt} + \frac{dD}{dt} &= a \frac{I(N - A)}{I + N - A} \\ \frac{dA}{dt} &= a \frac{I(N - A)}{I + N - A} \quad \dots \text{from (9)} \\ a &= \left( \frac{1}{I} + \frac{1}{N - A} \right) \frac{dA}{dt} \quad (19) \end{aligned}$$

However, it is to be noted that as reproduction number  $R_0$  which is a measure of virus multiplication, clearly the number of infections an infected individual produces is given [2] by,

$$R_0 = \frac{\beta}{\gamma} \quad (20)$$

Depends on time with the lockdown measures, the properties of virus and its mutation, etc. factors. These all factors are the functions of time. Considering that  $\gamma$  is constant with time, (17) clearly implies that  $\beta$  is the function of time. And in turn  $a$  is the function of time. However, for our calculations in the predictions, we will consider its mean value constant over further period of time in constant conditions of lockdown and without lockdown. Let  $a_l$  be the mean value of  $a$  calculated from previous records using (16) and  $a_{nl}$  is the mean value of  $a$  since outbreak till lockdown start. We assume that after lockdown the mobility of individuals is same as that was before lockdown. Let  $t_l$  be the time at which there is lockdown. With this our parameter ' $a$ ' becomes as,

$$a = \begin{cases} a_l; \text{lockdown} \\ a_{nl}; \text{no lockdown} \end{cases} \quad (18)$$

It is true the fact that the parameters  $b$  and  $c$  are as well as the functions of time as the recovery rate or death rate may be influenced by the immunity response of individuals or the herd immunity concept. However, the recoveries and death count in the initial stages of outbreak are relatively small and may not give enough characteristic or deviation to fit their curves,



especially after lockdown state. It is assumed that lockdown was taken immediately until the death and recovery count has not shown reasonable deviations. Hence we calculate the parameters  $b$  and  $c$  where they show a near constant trend and utilize their mean values for predicting the recoveries and deaths during and after lockdown. We will keep their values constant w.r.t time henceforth.

### C. The Nature of Solution curves and brief explanation to pandemic dynamics

The infected count curve is a distorted bell shaped graph as shown in Figure 1 in blue, the maxima of curve gives the peak magnitude and the time at which it may occur. The inflection point of this curve has maximum rate of infection. Both the death and recovery curve has a logistic nature.

This follows, as the susceptible population is infected, simply stated will either live or die. If they show resistance or higher immunity, the recovered compartment gets filled with a rate proportional to the infected count and who cannot sustain the disease will go in dead compartment with the rate proportional to infected count. As these two compartments get filled with time, there is decrease in active cases or the infected population. But at the same time the virus keeps on infecting the new individuals. At some time when the rate of infection is in the dynamic equilibrium with the recovery and death rate, the count of infections is at maximum which we here refer to as the peak of outbreak. After which all the rates come to a static equilibrium with infection and death rate reducing to zero asymptotically.

However, if we are having less initial data points, we cannot fit the curve with reasonable accuracy. This is because there is no characteristic deviation in parameters in initial stage. At this position it becomes very critical that even 0.1% change in curve parameters drastically affect the prediction.

### D. Sensitivity of parameters

It is observed that even 0.1 % change in these parameters especially a causes around 30% change in predicted values. It implies that even 10% improvement in recovery or decrease in infection rate can cause volatile change in predictions.

Also the data available to us is on daily basis so the minimum time step ' $dt$ ' we can take is of 1 day or 24 hours. It might be so that if the data is updated every 3 to 4 hours in a day there might be greater accuracy with  $1/8^{\text{th}}$  day or  $1/6^{\text{th}}$  day step as this model is a differential system and lesser amount of ' $dt$ ' is preferable for accurate parameter estimation.

### CONCLUSION

From this report we have tried to put forward some quantitative prediction, given some suggestions to various bodies of the society and execution and as well given a live tool in the form of spreadsheet which will enable any individual or authority to analyze and predict the COVID-19 outbreak in their areas.

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