How many tests does a city need to reopen?

There are 392 MSA in the USA.[1] These are defined to be areas which mix rapidly and which people are in frequent contact with each other. Though it is defined for more social, political and economic reasons, it is a good approximation of the regions we should be dealing with in planning for how to handle a ending lock down. Some of these areas are very easy to define, say a city in the midwest surounded by farm land. Alternatively, some are hard to tease apart for example where exactly should the line between Baltimore and Washington DC go? But, a good MSA is one that can't be further subdivided without lots of people crossing each day from one piece to the other. Treating Mahnattan as its own little island is not useful since half of the people who work there come from off the island.

We will use the following MSAs as our working examples:

Rank	**MSA**	**Population**
1st	NYC	20M
3rd	Chicago	10M
10th	Phoenix	5M
34th	Cleveland	2M
53rd	Tucson	1M
115th	Reno	500k
226th	Bend, OR	200k
356th	Grand Forks, ND	100k
384th	Carson City, NV	50k

Table 1: A sample of various MSAs.

The question we are addressing in this document is when

[1] I don't think we should use CSAs which are much bigger and sometimes overlap.

should an area open up from lock down? We will argue that they should do this when they have sufficient test and traces set up to handle the post-lockdown world. These cities are all unique in many different ways. So the plan described below makes the assumption that we have a good idea of what exactly an "opened city" should look like. For a large number of jobs the answer has to be yes for it to qualify as open. But, restaurants? Shows? Sports? Masks? Etc. These are questions for which there are good guesses, but we might not trust those guesses for a particular MSA. In that case, a good plan would be to slow the transition to being open so that we have evidence that we haven't opened too much and are in fact losing the battle with the virus.

Suggested plan

We propose following a three step plan. In the first step, called "Preparation for overkill" we keep things locked down but start testing and tracing at scale. Our goal is to inform a large fraction of all the infected people that they are COVID positive and so shouldn't leave isolation when the lockdown is lifted. This phase should last for a minimum of 5 days. If at the end of this time, we have enough tests and tracers to handle the actual number of cases we expect, then we are ready to open. If we have enough, we will either need to procure more tests and tracers, or wait for the infection rate to decrease until the quantity of daily infections could be handled by the number of tests and tracers we have.

We then open up with massive scale testing and tracing. We call this "Overkill" since we want to hit it as hard as we can. Hitting it hard will save on the total number of tests we need. Hitting it hard will mean the majority of the tracers can get back to other activities in a few weeks. Hitting it hard simply saves lives. So, we are willing to go into this phase planning on consuming more tests and more tracers than might strictly be necessary since it will save effort in the long run.

Finally, after we have gotten the rate of infection down we can let most of the tracers go back to their pre-COVID jobs. During this "maintaince" phase, we will still need testing and tracing since new infections will keep popping up. Either from neighboring cities, or from people who were slow to show infection. This will end up consuming very few tests and allow a close to full opening of society. About the only things that might still be restricted here is allowing people to vacation from highly infected cities.

Testing and tracing needs

Initial resources needed to reopen various MSAs

region	**Pop**	$\frac{\textbf{Deaths}}{\textbf{day}}$	$\frac{\textbf{new infections}}{\textbf{day}}$	$\frac{\textbf{Test}}{\textbf{day}}$	$\frac{\textbf{Tracers}}{\textbf{day}}$
MSA (total deaths)	P	D	$N \approx P/\,\mathrm{IFR}$ $\approx 100P$	$T = cN$ $\approx 30N$	VN $\approx 5N$
NYC (12k)	20M	200[a]	20k	600k	100k
Chicago (1300)	10M	40[b]	4k	120k	20k
Phoenix (122)	5M	5[b]	500	15k	2500
Cleveland (96)	2M	5[b]	500	15k	2500
Tucson (76)	1M	2[b]	200	6000	1000
Reno (219)	500k	15[b]	1500	50k	7k
Bend (0)	200k	.1[c]	10	300	50
Grand Forks (0)	100k	0[c]	10	300	50
Carson City (219)	50k	10[b]	1000	30k	5k

[a] Seven day average.

[b] Estimated as total deaths divided by 10.

[c] We will take about one per week as our minimum daily death rate for computing the number of tests and tracers.

Table 2: Estimating D = total/30 except for NYC.

region	**Pop**	**tests need in**		
		month 1	**month 2**	**month 3**
NYC	20M	10M	2M	500k
Chicago	10M	2M	500k	100k
Phoenix	5M	250k	50k	10k
Cleveland	2M	250k	50k	10k
Tucson	1M	120k	30k	10k
Reno	500k	500k	100k	25k
Bend	200k	20	20	20
Grand Forks	100k	10	10	10
Carson City	50k	500k	100k	25

Table 3: Estimated number of tests needed in the first few months. Notice it is mostly a function of the number of initial infections and not the population. {**dpf:** *We need to fill this in for all MSAs.*}

APPENDIX

Parameters

MSA data:

D = number of deaths per day in the MSA at the start

N = number of new infections a day the MSA at the start

P = population of MSA

Assumed parameters:

V = Total tests done per per positive test result (30 to 50)

IFR = Infection Fatality Rate = 1/100 to 1/50

H = Typical duration of overkill phase (half life = 15 days)

m = rate of new infections during maintence (= 1/5 million estimated from SK){**dpf:** *Can we get a higher number from Daegu SK, Soul SK? Can we estimate how many people move across MSA boundaries?*}

c = trace team in days of effort = 5

Key result variables:

initial estimate of N = $D/\,\mathrm{IFR}$

initial tests per day = VN

Q = Tests needed during overkill phase = $2VHN$

q = Tests needed (per day) during maintenance $= PmV/(1-R)$[2]

T = number of tracers initially $= Nc = cD/\,\mathrm{IFR}$

t = number of tracers needed during maintenance $= Pmc$

total tests needed = for MSA in first year $= 2HVN + 365 \times mP$

Before we are testing a total of VN per day, we will likely be missing lots of new infections. So a good rule for estimating N is simply $1/\,\mathrm{IFR}$ times the number of Deaths. So, we start with an initial guess of $N = D/\,\mathrm{IFR}$ or about $50 \times D$ to $100 \times D$. Each new infection needs a contact team to focus on it as soon as it is discovered. Most of the effort of that team should be on that new discovery and as rapidly as possible tracing the infection to other people. Assuming a contact team spends a full day on each case and consists of c members, then, we need T = cN. So, before we are testing at $20 \times N$, we will start with a guess of $T = cD/\,\mathrm{IFR}$ or about $250 \times D$. This is the number of initial tracers we should start with in a MSA.

[2] {**dpf:** *Add/delete an R? $PmV/(1-R)$.*}