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Exit strategy: from self-confinement to green zones

EsadeEcPol Insight #6 April 2020

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SUMMARY

— The Covid-19 pandemic has put the world to an unprecedented test. A wide range of social distancing and confinement measures have been implemented to reduce the progression of infections. Returning to normality is the next challenge. It is important to avoid a resurgence of the virus while minimising the societal and economic damage. We propose a practical exit strategy that is based on two key elements: identifying green zones, and progressively joining them together once it is safe to do so. Supported by simulations, we show how territories could be rapidly unified, within two to four months.

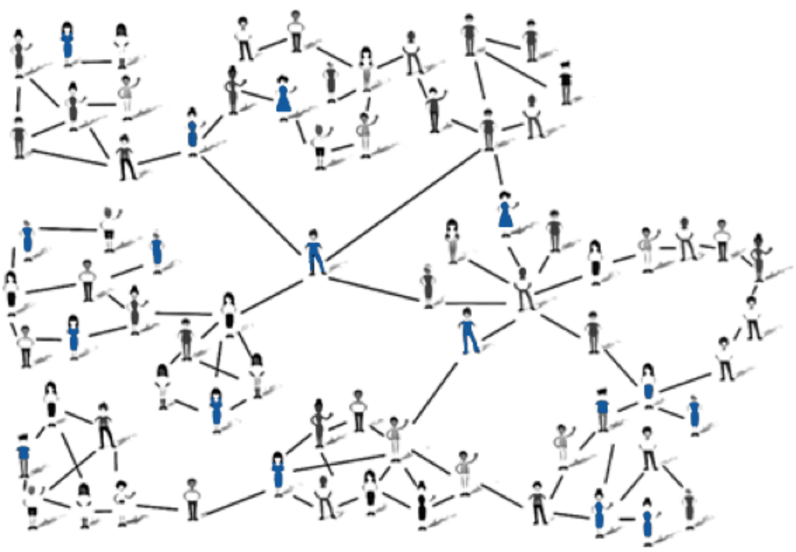
Physical proximity networks

The current outbreak of Covid-19 exemplifies **how exponential growth leads to a quick acceleration in the number of infected people** even when early in the pandemic the number of infected people is small. The propagation of the virus happens via physical proximity, meaning direct contact between two people (handshakes, kisses and hugs) or touching objects contaminated with droplets containing the virus. It is, therefore, useful to consider that we all form a large and dynamic network of interactions.

We are all familiar with the Facebook network, where every person has over 300 friends on average, and each of these connections is a link in the network. The distance between two people is naturally measured as the number of intermediate links between them. The idea of "six degrees of separation," first formulated in the late 1920s, is that everyone in the world can be reached within at most six links. Curiously, this conjecture was formulated for the network of handshakes, a network that is defined by physical proximity.

Because of the spread of Covid-19, we are interested in the **physical proximity** where two people are connected only if they currently share physical proximity (see the figure below for an example network). Disconnecting or weakening this extensive network is the key purpose of social distancing and lock-down measures.

Figure 1
A human network



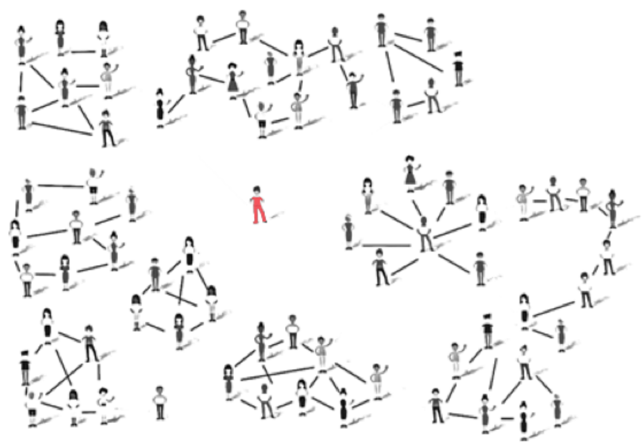
Sanitary measures, social distancing and lock-down

In an ideal world every person could be tested simultaneously (and tests would return the correct result with certainty). In reality, t**esting is limited,** not simultaneous, and does not return the correct result with certainty. Therefore, while some rules and recommendations are based on observable information, others inevitably include everybody.

Rules and recommendations differ from one country to another but are progressively reaching consensus and all aim to eliminate links – or at least reduce their intensity in the physical proximity network. Firstly, by **reducing the intensity of direct contact** with social distancing (two metres between people outside the household) and sanitary measures such as frequent hand washing, coughing into the elbow and wearing face masks. Secondly, by **eliminating as many links as possible from the network** with more severe lockdowns.

Lockdowns vary in severity. For example, in France everyone should stay within a one kilometre of their home, while India's prime minister, Narendra Modi, recently ordered "a total ban on venturing out your homes" in a televised address. It is now almost impossible to travel between European countries, thus rendering them separate sub-networks of the physical proximity network (see figure below).

Figure 2
The virus cannot travel between disconnected sub-networks



Rules regarding observable information include **home quarantine for returning citizens,** for individuals self-identifying with symptoms (such quarantine is recommended to last for 14 days). Several countries have also changed their data privacy laws to allow citizens to be tracked via their mobile phones.

At this stage of the pandemic the sometimes very strict measures appear to be the only viable strategy for flattening the curve of new infections and reducing the spread of the virus, as appears to have been achieved in China and South Korea.

An empty metro station in France during the Covid-19 outbreak (Photo: L. Genet/Wikimedia)

Zoning

Partitioning the world population into disconnected components, in terms of physical proximity, is the **key purpose of lock-down.** Most countries have closed their borders. However, these measures are ineffectively mirrored within countries, for example many flights are running within the United States.

As already mentioned, in France people are asked not to go more than one kilometre from their homes. Although such a measure is useful to slow down and reduce interactions, the virus can still travel through the entire network. In a city of the size of Paris, two people who are two kilometres apart may still share the same grocery shop, and thus everyone in a 10-kilometre diameter of the city is connected within five degrees of separation in the physical proximity network.

Instead of enforcing a radius of movement for each individual, we propose to **let people move within disconnected areas,** such as towns or districts (or Parisian "arrondissements"), in order to cut the physical proximity network into disconnected pieces, and thus prevent the virus from travelling throughout the territory.

Specifically, two Parisians living in different suburbs cannot infect each other, even via intermediate steps. This would have the important advantage that tracking the contagion and evaluating which zones are at higher or lower risk becomes much more feasible. Also, the idea of **fencing between infected and healthy communities,** termed *cordon sanitaire and reverse cordon sanitaire,* has been deployed during a variety of outbreaks for centuries.

Building on these ideas, we propose a safe, efficient and easily controlled exit strategy from the Covid-19 pandemic. Social and economic interactions can return to a normal level rapidly by progressively **joining safe zones together** (while maintaining a high level of testing).

How to rebuild our links: green-zoning

The zoning approach should play an important role in the exit strategy from the Covid-19 pandemic. After the initial spread is contained, we focus on **how to transition back to a normal life,** that is, how to rebuild the physical proximity links.

To control the process and the inevitable partial resurgence of the virus we advocate an approach that was labelled "green-zoning" in a recent article by Monràs[1].

Illustration

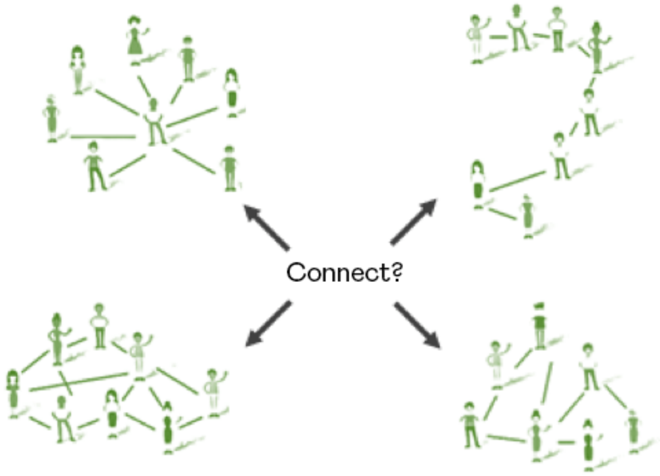
To illustrate, consider a town with some 10,000 inhabitants where most people work in a local factory, or in other occupations within the community. Once no new infections have been detected for seven consecutive days (despite thorough randomised testing) we propose labelling the town as green, meaning that its inhabitants can progressively return to their usual social and economic interactions.

Testing for Covid-19 before re-introducing interactions would **accelerate the eradication of the virus** as has been showcased in an Italian town [2].

After this initial step, several green zones with an average size of 10,000 people will be identified. The subsequent process resembles the initial step. After each **seven-day period without any cases within a green zone** a small number of neighbouring green zones (for example, between two and ten on average) are allowed to join to form a larger green zone. In this way, ever-larger green zones are created with people sharing the same shops, workplaces, parks and schools.

Within a green zone, **inhabitants should feel as secure** as during their initial individual confinement because there is evidence (negative tests and no more infections) that supports the absence of the Covid-19 virus in the zone.

Figure 3
Four neighbouring green zones merge into a larger green zone



Analysis and results

Due to the imperfection of testing and zoning, **some green zones will inevitably have a resurgence of infections,** and thus cease to be "green."

When this happens, the green labelling of the entire area is lost, and we **go back to the previous lock-down situation,** so as to identify and confine the new cases. We formalise a model which will be used to evaluate the impact of these new infections on the process of identifying green zones.

We propose to **partition a nation into cells** that are given by a town or area with an average of 10,000 inhabitants. The figure below shows an example partitioning of the Ile-de-France area surrounding Paris. To limit economic damage, this partition should consider "commuting zones" as introduced by Charles Tolbert and Molly Sizer [3].

The partitioning of a territory can be done in various ways. Here, we illustrate the partitioning of the French region Île-de-France into small geographical cells ("communes") which also belong to progressively larger areas ("départements" and "régions," respectively).

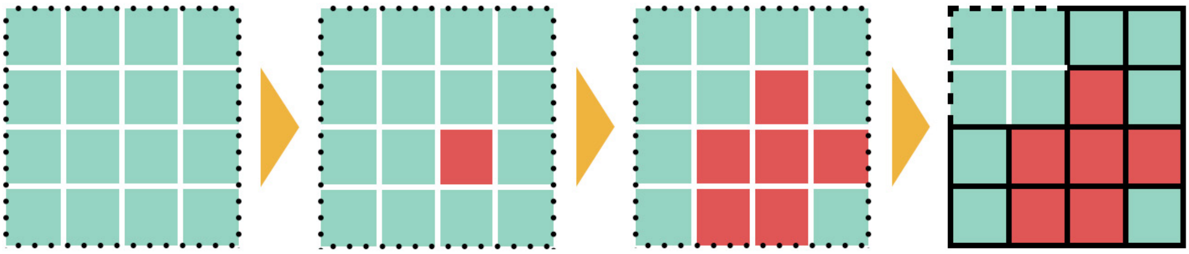
Dynamics. Each cell is labelled red or green according to the current status of its inhabitants. Green cells are regions currently free from Covid-19, while red cells denote infected regions. Each day, new infections are potentially detected, and the rate at which this occurs depends on the number of red cells. Newly infected cells contaminate some of the neighbouring cells, and the infection in each cell lasts a random number of days. While red cells remain isolated, green cells are progressively united to form larger green zones. Thus, both the colour of cells, and the size of green zones, evolve over time. The war against the virus will be over once all cells are rejoined into a single green zone.

Red-zoning. When a new infection is detected in a cell that is part of a green zone, this zone is progressively broken into its smaller constituents, until each red cell is isolated. The inhabitants of red cells remain isolated (i.e. under strict monitoring or on a lock-down policy).

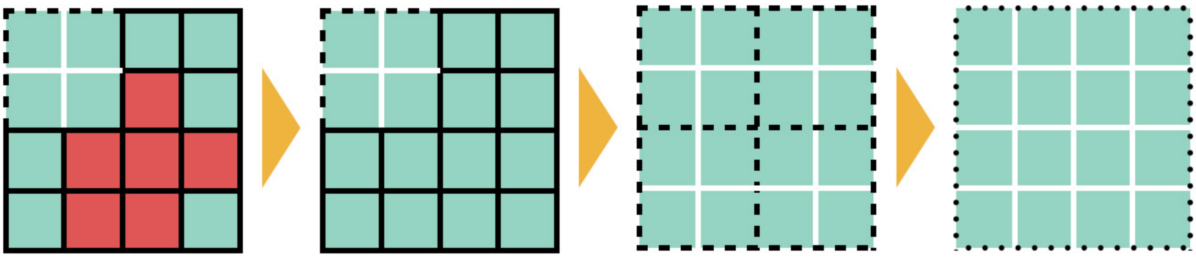
Green-zoning. Zones that do not record new infections despite thorough randomised testing are labelled green after seven days. After seven additional days, neighbouring green zones are merged to form a larger green zone. Within these zones, interactions are again progressively allowed, albeit with some restrictions.

Figure 4

In this figure, we use a simplified partition of an area into 4x4 cells and three levels of zoning: 1x1, 2x2 and 4x4.



Red-zoning. A new infection is detected in a 4x4 green zone (step 1). This triggers testing for Covid-19 cases within the area, and so other infections are detected in the surrounding cells (step 2). Green-zones are revised to contain the virus (step 3).



Green-zoning. After a random number of days (between 14 to 28 days) all cells return to green (step 1). After seven days, the green cells merge to form larger green zones (step 2). After seven more days, the green zones merge into a larger green zone (step 3).

Results. This re-unification process appears to be tedious, as the size of the green zones, while often increasing, may also decrease. However, as soon as the probability of new infections is controlled, the proposed process will enable an exponentially fast return to normality. Based on our simulation study (see the appendix), the entire re-unification of a country such as France (67 million inhabitants) would take between 2 to 4 months, assuming sufficient sanitary measures are maintained and testing becomes more widely available.

Advantages of green-zoning

While green-zone merging requires a careful process, it is very efficient as the spread of green zones is exponential, just like the spread of a virus.

The difference, however, is that **we choose who to merge and when;** and we keep track in case we need to return to a lockdown. In some sense, we deconstruct society into its fundamental blocks before reconstructing society from these same blocks.

The meaning of a green zone can vary from one country to another and change over time. For instance, green zones could enable full interaction within an area, or interaction among a fraction of the population (inhabitants who are at low risk – based on age or medical pre-conditions), or with restricted interaction that prohibits gatherings of more than 50 people and requires other social distancing measures (such as wearing face masks).

In summary, the advantages of green-zoning are:

Minimise economic damage.
By re-opening zones with strong economic links, such as the commuting zones defined by Tolbert and Sizer [3], overall damage can be significantly reduced.

Non-invasive tracking.
The inevitable resurgence of the virus in some green zones is easily located. This macroscopic tracking method complements the microscopic tracking via Covid-19 tests and frequent body temperature checking, but it does not interfere with privacy (i.e. there is no need to track inhabitants through their mobile phones).

Minimise societal damage.
Social distancing may lead to mistrust and various forms of ostracism within society. Slowly restarting normal relationships with neighbours and colleagues in an organised manner can help overcome these newly learned unsocial behaviours.

Quick re-unification process.
The simultaneous merging of zones leads to an exponentially decreasing number of zones. This enables the process of rebuilding and restoring a physical proximity network within a few months.

Easily combined with other measures.
As the notion of a green zone is flexible, it can be adapted to fit the current possibilities of each region, e.g. availability of testing or immunity certificates, practice of sanitary precautions, voluntary social distancing, etc.

Policy implications

To reap the full advantages that green-zoning offers, important **policy choices must be made** and complementary measures must be implemented, such as wide-spread testings (see the Nobel laureate Paul Romer's blog [4], for an enlightening discussion) and adherence to high sanitary standards. The following steps are inherent to the green-zoning approach:

1. **Delimitation of zones.**
Define cells and zones respecting social and economic ties as much as possible. It should not be assumed that existing partitions (such as the commune, *departement,* and region partitioning in France) are the most appropriate. Economic commuting zones as well as other constraints, such as the possibility to control the access and conduct tests at the borders of zones should be considered.

2. **Meaning of red and green labels.**
Specify (for example, on a weekly basis) what living in a red or green zone means for its inhabitants in terms of sanitary rules (for example, no hand shaking and obligatory face masks), any restrictions based on age or medical pre-conditions, and the intensity of testing inside each zone and at its borders as key workers will still have to cross them.

3. **Informing the population.**
Information about current zoning and its implications should be available at all times. This can be implemented via an online platform, a mobile application, or announcements on radio and TV.

4. **Enforcing the zoning.**
Finally, it is crucial to gain public support. As during the lock-down, different countries have used a number of measures that range from recommendations, rules with hefty fines, to the tracking of each citizen's movements via their mobile phones (see Singapore's Trace Together application).

Conclusion: a safe and efficient path towards a new normal

The Covid-19 pandemic is putting mankind to the test. A highly connected world – modelled via a network – accelerated the spread of the virus to almost every country in the world within a few weeks. The initial response to this pandemic builds on sanitary measures, medical research, economic easing, and perhaps most importantly of all, clearly communicated and coordinated policy decisions. The wide-spread measures enforcing social distancing, often via a lock-down, have become the consensus short-term response.

The time has come to consider an exit strategy. We argue that this second phase can be orchestrated in a safe, efficient and easily controllable way. By re-building our social and economic interactions through the **progressive enlargement of green zones we will reach re-unified countries within two to four months.**

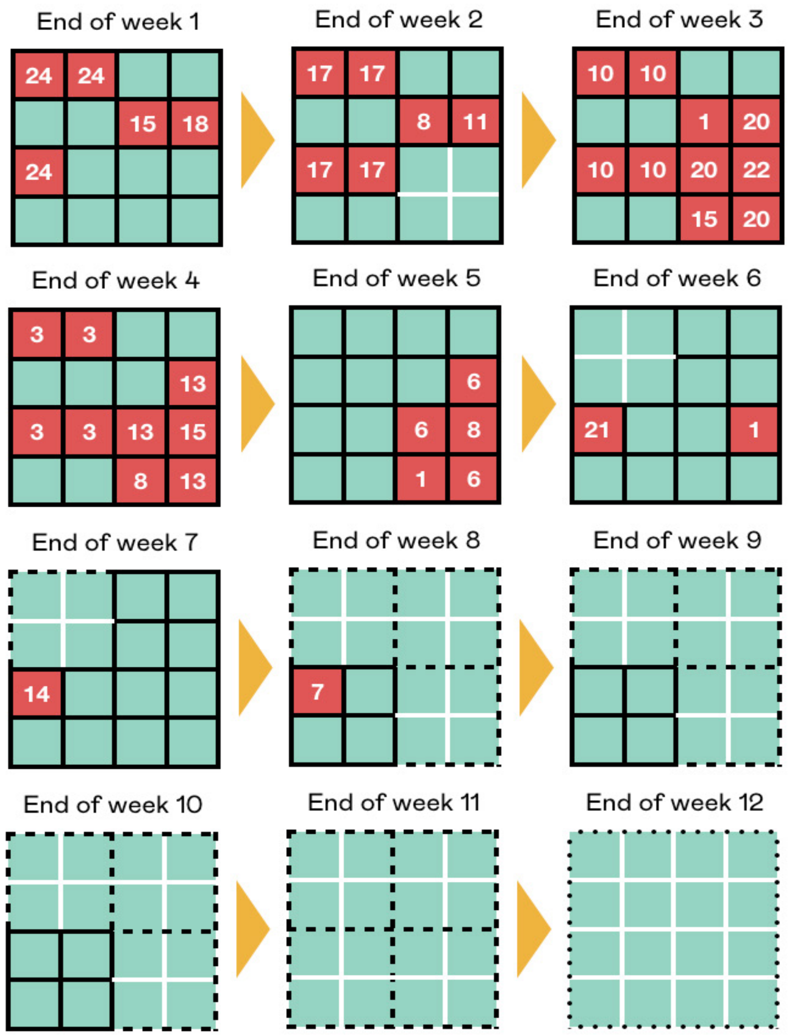
Our approach does not require tracking inhabitants at a personal level, and thus **respects individual privacy.** This approach is compatible with most of the measures that are currently under discussion. In summary, we firmly believe that green-zoning can play an important role in minimising societal and economic damage

Appendix: An example simulation run

The full simulation study is currently in preparation for publication and can be provided by the authors. Our mathematical model serves to test the process of green-zoning. It is not calibrated to a particular country, and does not take into account the detailed behaviour of the virus. For this reason, any number that emerges from it should be taken as a qualitative indicator, and not as a reliable prediction.

Here, we show below a simulation run for an area consisting of 4x4 cells, five of which are initially infected. Each day, every cell is infected (or re-infected) with probability p I, where p=0.005 and I is the current fraction of red cells. These infections instantaneously spread to a fraction q=0.95 of the cells inside the corresponding green-zones, and each newly infected cell is attributed a random number of days d (between 14 and 28) before it returns to green.

Figure 5.
Example simulation run



Our simulation shows the situation at the end of each week, and the number inside each red cell denotes the number of days before it turns green unless it is re-infected. First of all, note the infection of the cell at (3,2), i.e. 3rd row 2nd column, during week 2. As this cell is isolated, the infection does not spread. Second, note the re-infection of the cell (2,4), and the infection of the entire 2x2 green zone during week 3. Third, a new infection was found at cell (3,1) during week 6. Lastly, observe how the entire area is progressively united after this point.

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