

# Assessing the effectiveness of perimeter lockdowns at the urban scale: the case of Madrid

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# Background

## Epidemiological context

Second wave of COVID-19 building up (September 2020).

## Socioeconomic context

- Madrid wanted to avoid hard generalized lockdown, emergency state and any imposition from Central Government.
- Want to avoid "economic ruin" and sought for softer alternatives.



"Madrid belongs to everyone. Madrid is Spain inside Spain. What is Madrid if not Spain?" - Isabel Díaz de Ayuso, President of Autonomous Community of Madrid.

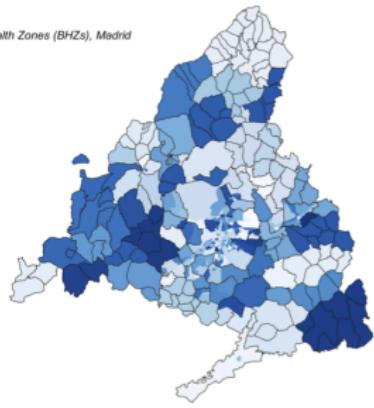
# The strategy: Perimeter lockdowns for Basic Health Zones

## What are they?

PLs: Cut down mobility in-and-out of areas under risk

BHZs: minimal areas with basic public health support.

Basic Health Zones (BHZs), Madrid



from García-García et al. (2022)

- First round of lockdowns: Sep 23.
- 37 BHZs affected in the whole region.
- Time extension: 14 days or more...
- Prerequisites?
  - 14 days cumulative incidence rate above 1000 cases per every  $10^5$  inhabitants.
  - Increasing trend.
  - Observation of community spread.

# Framing the problem

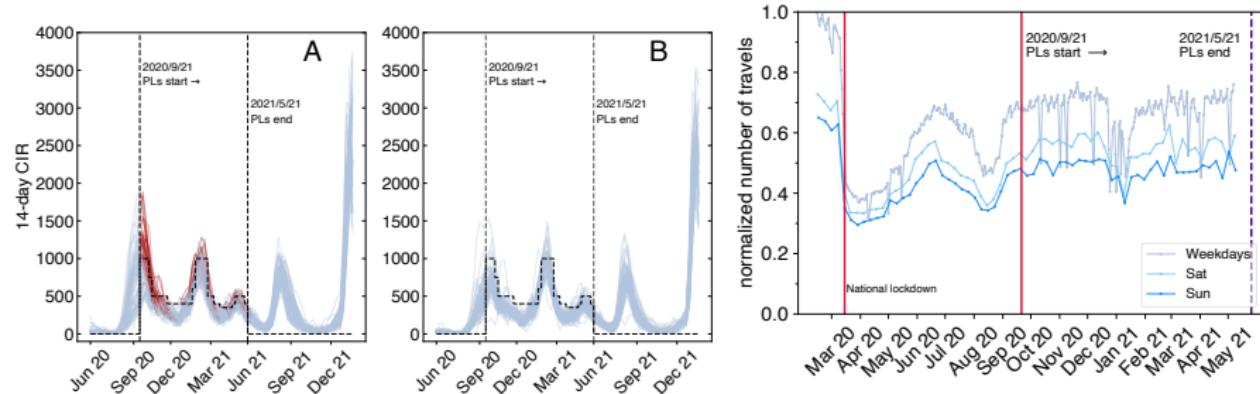
## Question

Is this a good control strategy?

## Our work and aims

- Qualitative inspection of epidemiological data from Madrid.
- Devise a general, minimal and mechanistic model of perimeter lockdowns.
- Explore under which circumstances could work.

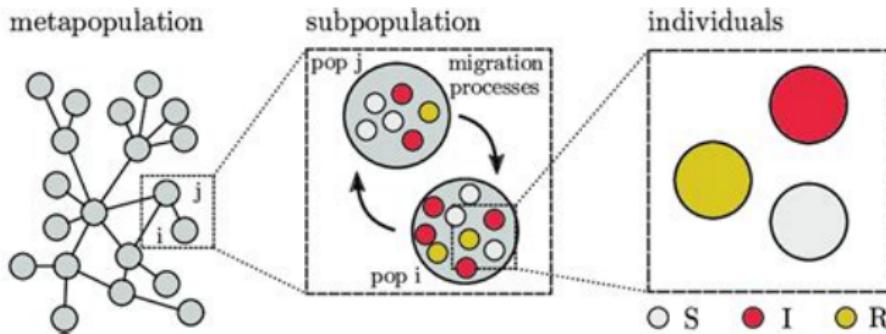
# Inspection of real data



- Peak incidence & activation occurs around same time in 1st round.
- Literature confirmed that measures had no real effect.
- Threshold criterion? Moving like waves & some free zones above it.
- Highly synchronized time series + No meaningful effect on mobility.  
→ Seems like a dubious realization of the strategy.

# Framework: Network metapopulation

We built a data-driven metapopulation model for Madrid.



from Colizza & Vespignani (2008)

**System:** Nodes are entire populations and edges mobility are flows.

**Epidemic:** Homogeneous-mixing SIR within nodes.

**Mobility:** origin-destination matrices with real data from a pre-COVID-19 reference period.

**Mobility parameter  $\kappa$**  to control baseline flows ( $\kappa \rightarrow 0$  no one moves).

# More modeling details

**Response:** How are perimeter lockdowns implemented?

- 14-day cumulative incidence rate per  $10^5$  inhabitants as the monitoring variable.
- Set a **risk threshold**  $\Theta$ . If  $14\text{d CIR} > \Theta$  in a district  $i$ : we activate perimeter lockdowns.
  - Mobility:  $\kappa_{ij} = \kappa_{ji} = 0$  for  $i$  and  $\forall j$ .
  - **Local transmission rate reduction fraction**  $\chi_i$  so that  $\beta_i = \chi_i \beta$ , where  $\beta = R_0 T_I$ .
- Below threshold districts:  $\kappa \neq 0$ ,  $\chi = 1$  (nothing happens).

**Parameters:**

- $R_0 = 1.25$  (< COVID-19's)

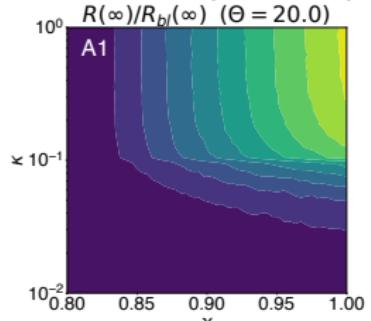
**Observables:**

- Final prevalence.
- Fraction of locked districts.

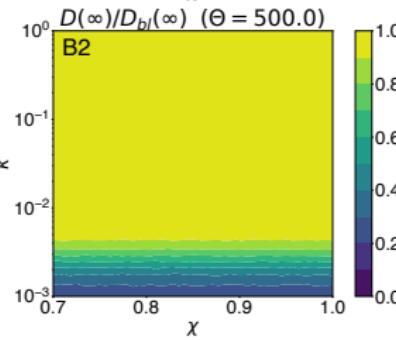
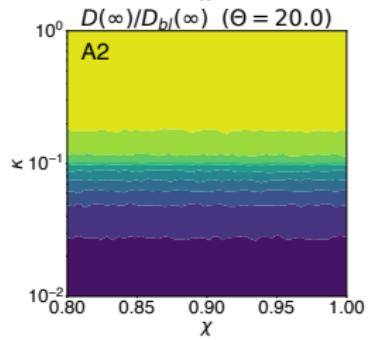
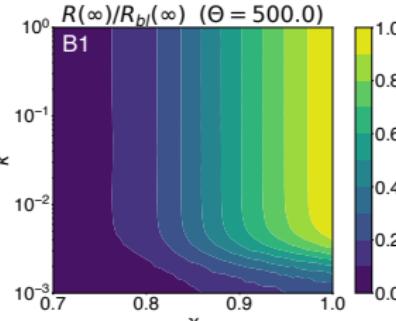
(both quantities normalized to baseline scenario: unmitigated spreading)

# Results: Hard to avoid a generalized lockdown

Left: Proactive strategy ( $\Theta = 20$ ).



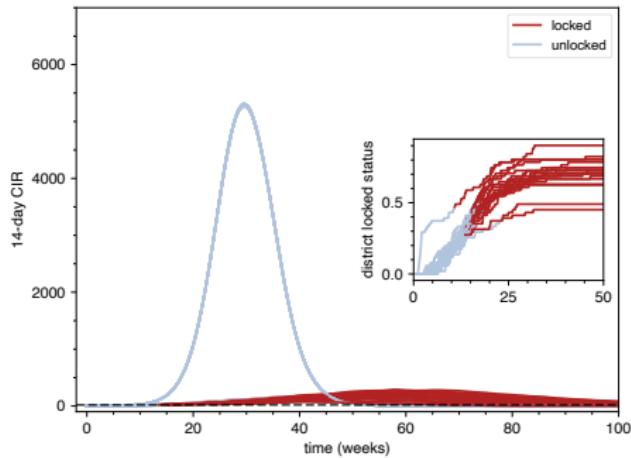
Right: Reactive strategy ( $\Theta = 500$ ).



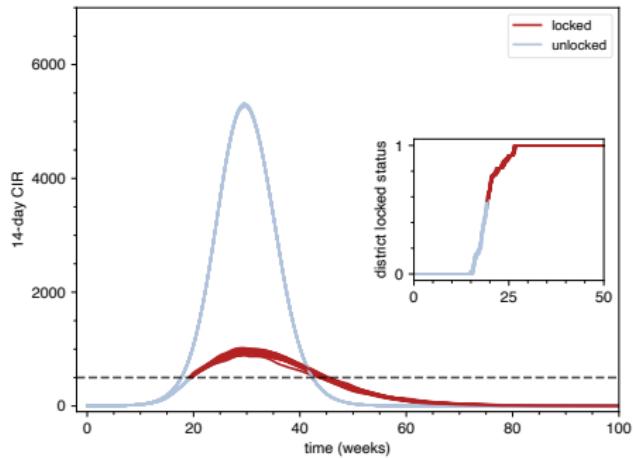
- Reducing  $\chi$  the most effective thing. (Hard to achieve?)
- Mobility  $\kappa$ ? Does nothing until ridiculously low values!

# Results: Local outbreaks highly synchronized

Left: Proactive strategy ( $\Theta = 20$ ).



Right: Reactive strategy ( $\Theta = 500$ ).



- Doing something better than nothing (indeed).
- Local outbreaks are highly synchronized.

# Conclusions

## Take-home messages:

- Urban scale → Small and well-interconnected systems → outbreaks highly synchronized.
- If aim is to protect some parts of the system...
- Lockdowns have to be activated unrealistically soon and tight.
- Restricting mobility by itself does nothing.

## Limitations (good and bad for the strategy's fate):

- SIR is too simplistic but it is a best-case scenario.
- Measures are activated instantaneously and with absolute compliance.
- Homogeneous-mixing at district level (future works).
- Markovian mobility and too-coarse resolution (future works).

**THANKS FOR YOUR ATTENTION!**



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## Quick literature review

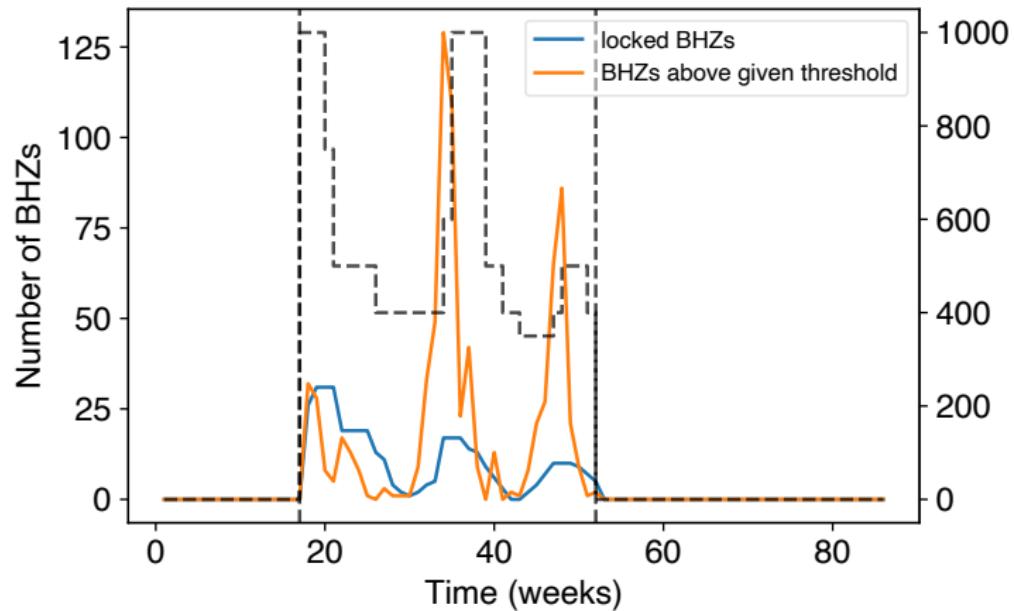
### Santiago de Chile [Li et al. (2021)]:

- “localized lockdowns on their own are **insufficient to control** pandemic growth in the presence of indirect effects from contiguous neighboring areas that do not have lockdowns.”
- “the epidemic is only controlled when generalized lockdowns are in place.”

### Madrid:

- Candel et al. (2020). (et al: includes Madrid's Public Health vice counselor) Tell and sell their management of the COVID-19 situation.
- Fontán-Vela et al. (2021): “According to our analysis, the decrease in the epidemic curve started **before the impact** of the perimeter lockdown could be reflected.”
- García-García et al. (2022): “Our analysis suggests that the perimeter closures by Basic Health Zone did **not have a significant effect** on the epidemic curve in Madrid.”
- Replies to Candel et al. (2020) harshly criticizing the *propaganda*.

## Number of BHZs above threshold



- Apart from the strange moving threshold criterion...
- Huge number of free BHZs above threshold during successive waves (3rd and 4th global waves).

# Epidemic model

Within each subpopulation the following reactions take place:



with probability  $P_i(S \rightarrow I) = 1 - (1 - R_0/(T_I N_i))^{I_i}$ ,

- $R_0$  is the basic reproduction number of the disease,
- $T_I$  is the mean infectious time,
- $N_i$  stands for the number of individuals in patch  $i$ , and
- $I_i$  accounts for the number of infected individuals in such region.



with probability  $P(I \rightarrow R) = 1/T_I$ .

New cases stochastically sampled from binomial distributions.

Process iterated with  $\Delta t = 1$  day until absorbing state reached ( $I = 0$ ).

# Mobility model

Several approaches exist:

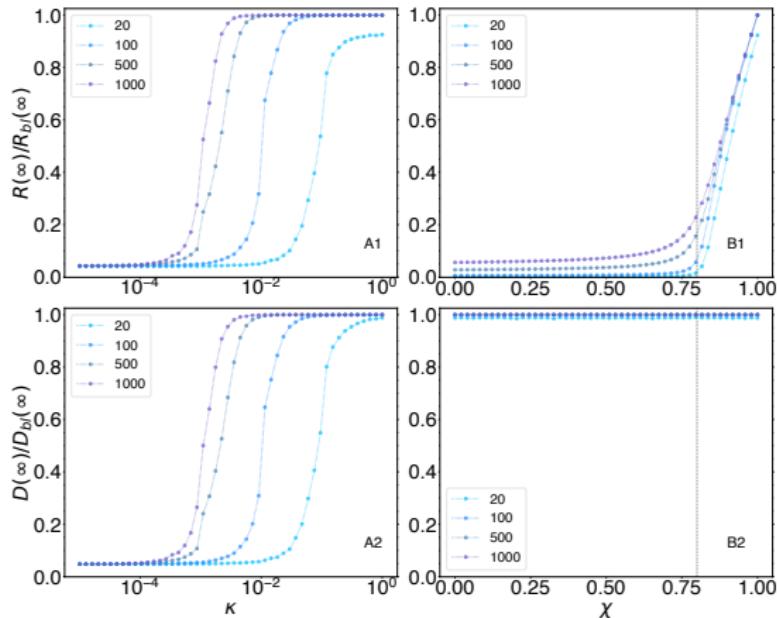
- Simple random walks assigning equal probability to traveling to any neighboring subpopulation.
- Degree-based travel, gravity, radiation models.
- Micro-mobility models (EPR and extensions).

Our approach here is **fully data-driven**:

- Data from mobility survey carried by the Spanish Ministry of Transport, Mobility and Urban Agenda.  
(<https://www.mitma.gob.es/ministerio/covid-19/evolucion-movilidad-big-data>)
- Build OD matrices  $\mathbf{M}$ : elements contain flow of travelers from  $i$  to  $j$ .
- Diffusion rate matrices. New travelers are extracted from multinomial distributions following rates:

$$D_{ij} = \begin{cases} \kappa \frac{M_{ij}}{\sum_j M_{ij}} & \text{if } i \neq j \\ 1 - \sum_{k \neq i} D_{ik} & \text{if } i = j \end{cases} \quad (3)$$

## Results: Phase diagrams



Left: fixed  $\chi = 1$ . Right: fixed  $\kappa = 1$ .

$\Theta$ : Restrictions should be activated very, very soon.

$\kappa$ : Mobility does nothing (until unrealistically low values).

$\chi$ : Focus on transmissibility (but departed from already low  $R_0$ ).