JURIX 2021

# AGENT-BASED MODELLING OF MOBILITY RESTRICTIONS AT A LARGE SCALE: EXPLORING THE IMPACT ON THE COVID-19 SPREADING IN ITALY

Martina Fazio, Alessandro Pluchino, Giuseppe Inturri, Michela Le Pira, Nadia Giuffrida, Matteo Ignaccolo

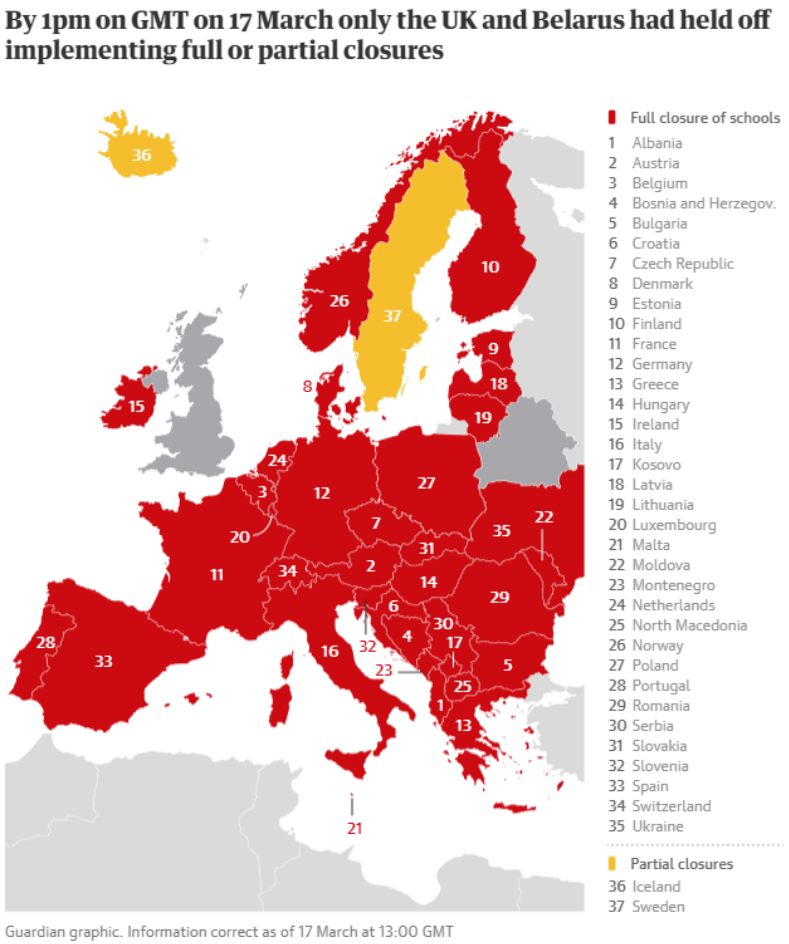
December 8, 2021

AM PM Agent-based Modeling for Policy-Making

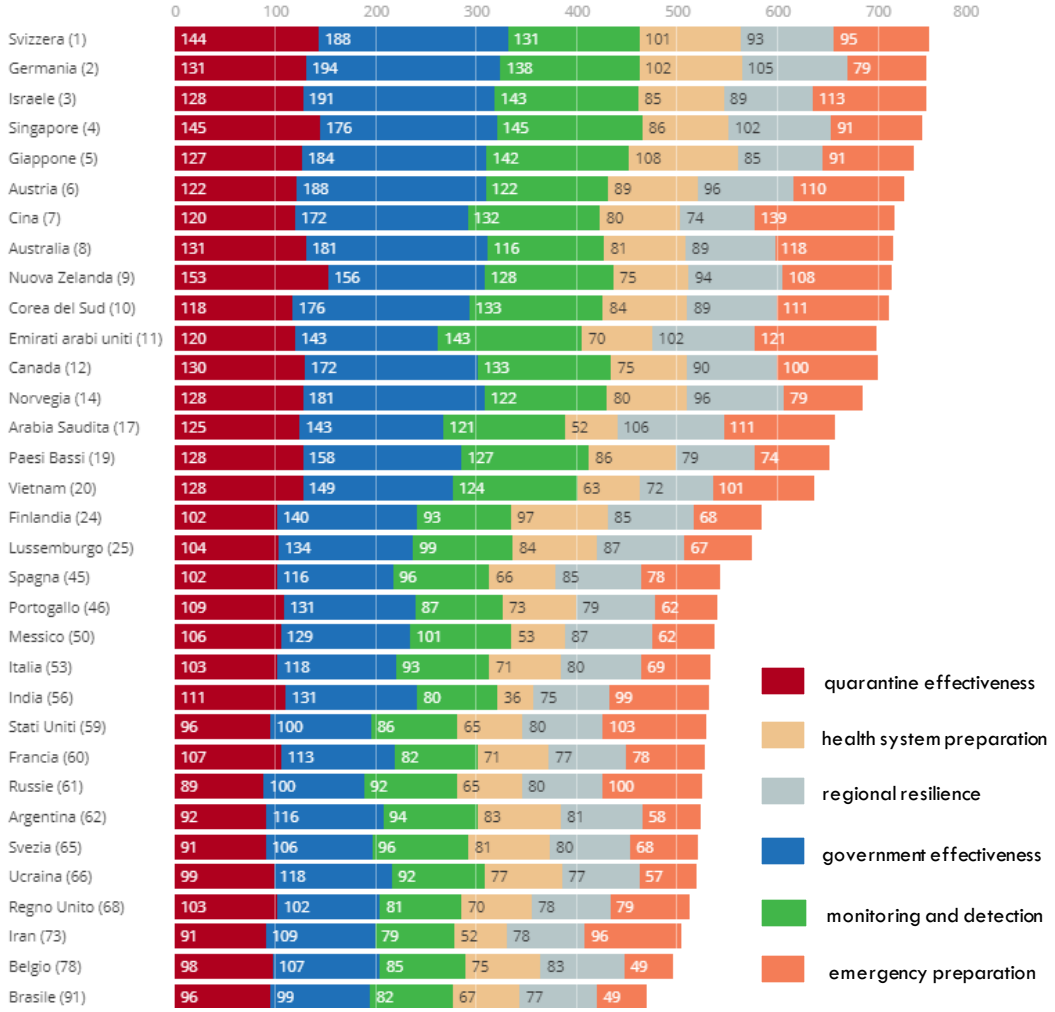
UNIVERSITÀ degli STUDI di CATANIA

# Motivation of the study

## Different confinement measures around the world



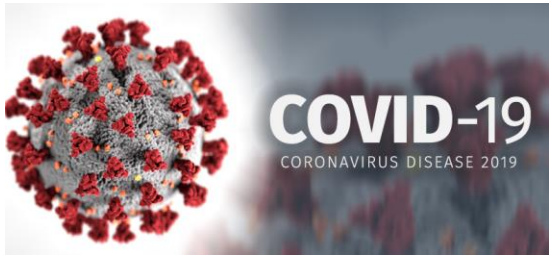

Source: https://www.theguardian.com/world/2020/mar/12/how-do-coronavirus-containment-measures-vary-across-europe

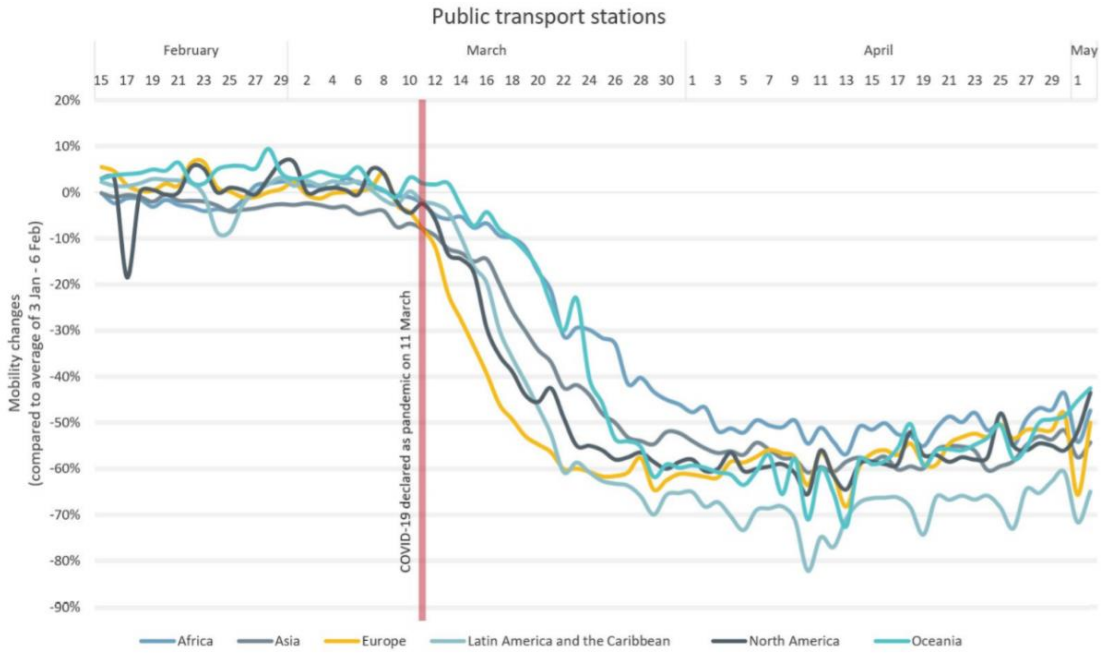



Source: https://www.swissinfo.ch/ita/covid-19--la-svizzera-%C3%A8-il-paese-pi%C3%B9-sicuro---secondo-uno-studio/45821272

# Aim of the study

## What is the actual effects on the virus spreading?



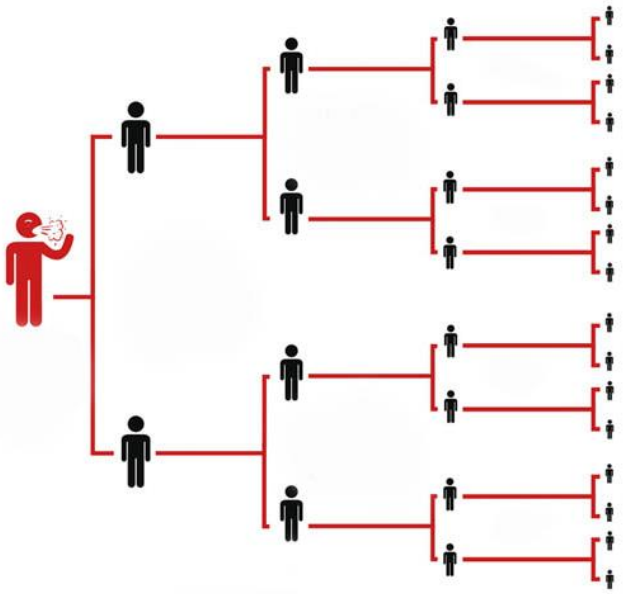

Source: https://www.iisd.org/sustainable-recovery/covid-19-recovery-a-game-changer-for-sustainable-urban-mobility/

- Simulating the effect of mobility restriction policies on the epidemic spreading
- Dynamic simulation through agent-based model (ABM)
- Case study: Italy
- Based on a Risk Model proposed by Pluchino et al., 2021
- Scenario analysis
- Suggestion of possible policy measures

# Model background

Kermack, W. O., & McKendrick, A. G. (1927).
*A CONTRIBUTION TO THE MATHEMATICAL THEORY OF EPIDEMICS.*

**Infection disease**



## SIR MODEL

SUSCEPTIBLE

INFECTED

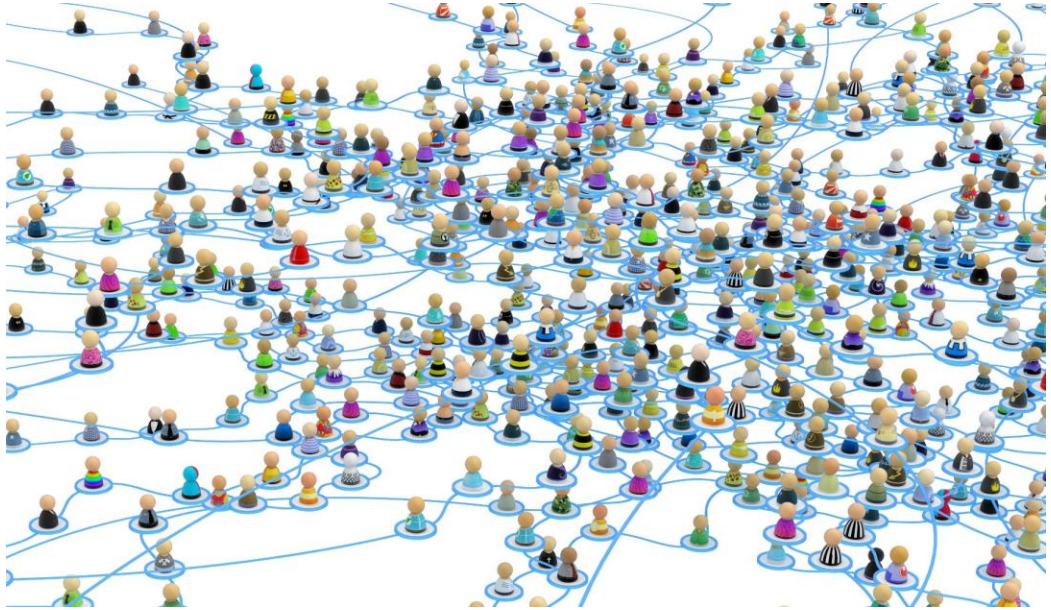
RECOVERED

- IMMUNE
- DEAD
- ISOLATED

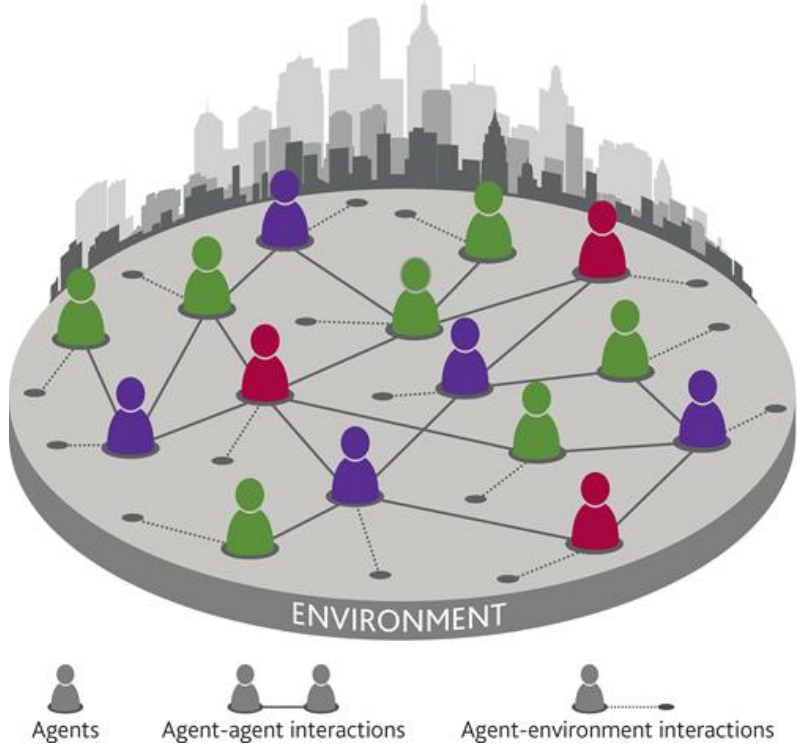
# Model background

- SIR model are unable to represent the complexity of human behavior
- Agent-based model (ABM) to simulate complex systems

## COMPLEX SYSTEMS



## AGENT-BASED MODELS



# Italian case Study

Lombardy
21st February, 2020

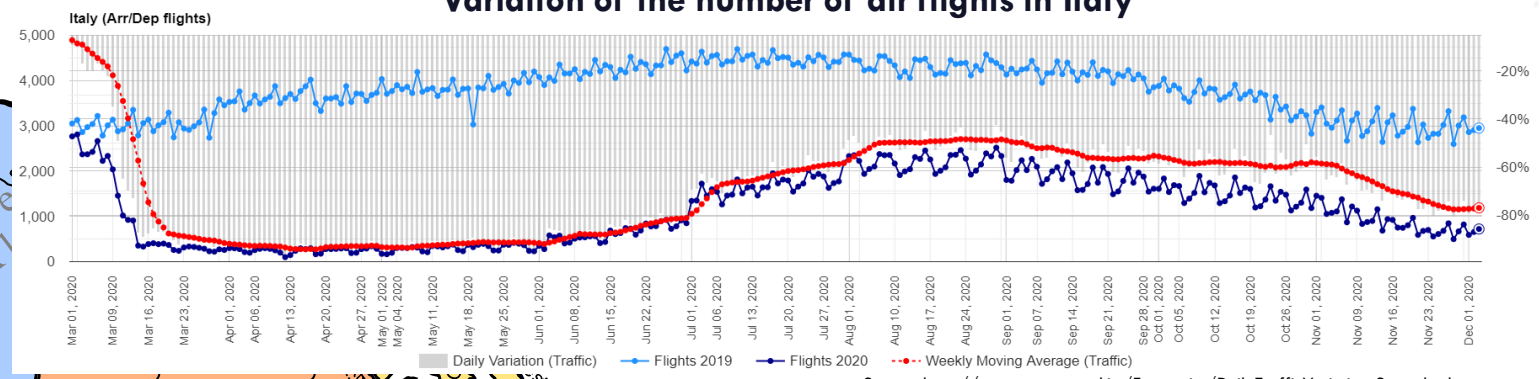
Veneto
21st February, 2020

Rome
23rd January, 2020

Government measures:
- 9th March, 2020
- 11th March, 2020

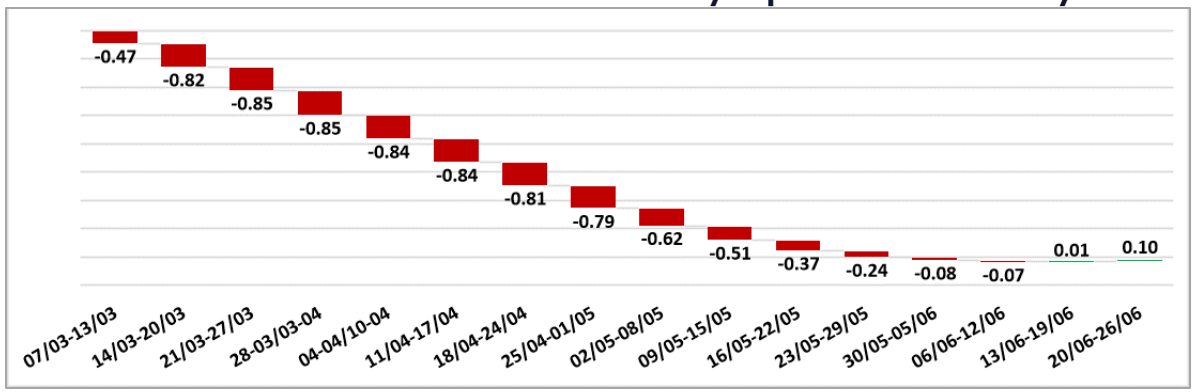
Mobility restrictions

## Variation of the number of air flights in Italy



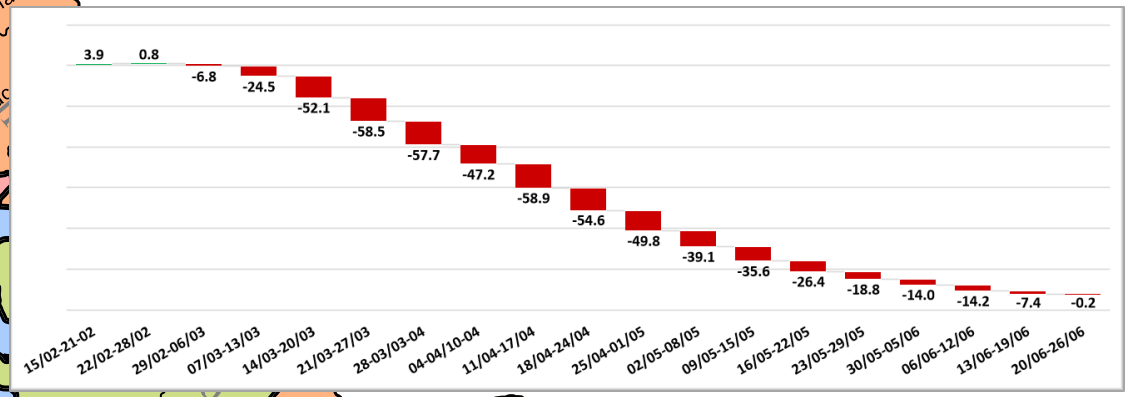

Source: https://www.eurocontrol.int/Economics/DailyTrafficVariation-States.html

## Variation of daily trips distances in Italy




Source: https://covid19mm.github.io/in-progress/2020/03/13/first-report-assessment.html

## Variation of the number of daily trips in Italy




Source: https://www.google.com/covid19/mobility/

# Methodology

## A RISK APPROACH TO COVID-19 OUTBREAK IN ITALY

scientific reports



Article | Open Access | Published: 05 March 2021

### A novel methodology for epidemic risk assessment of COVID-19 outbreak

A. Pluchino ✉, A. E. Biondo, N. Giuffrida, G. Inturri, V. Latora, R. Le Moli, A. Rapisarda, G. Russo & C. Zappalà

*Scientific Reports* **11**, Article number: 5304 (2021) | Cite this article

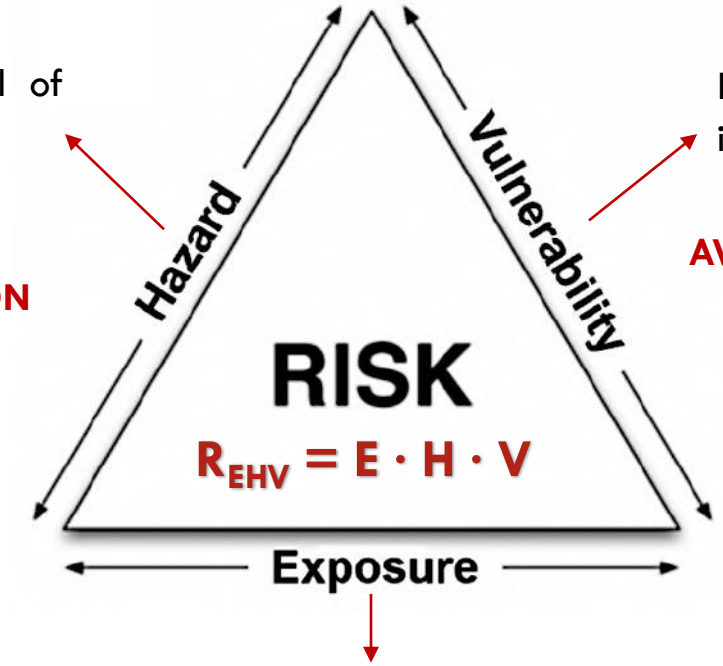
**5361** Accesses | **7** Citations | **23** Altmetric | Metrics

# Methodology

## CRICHTON'S RISK TRIANGLE

Related to the potential of an epidemic spreading

**MOBILITY INDEX**
**HOUSING CONCENTRATION**
**HEALTHCARE DENSITY**



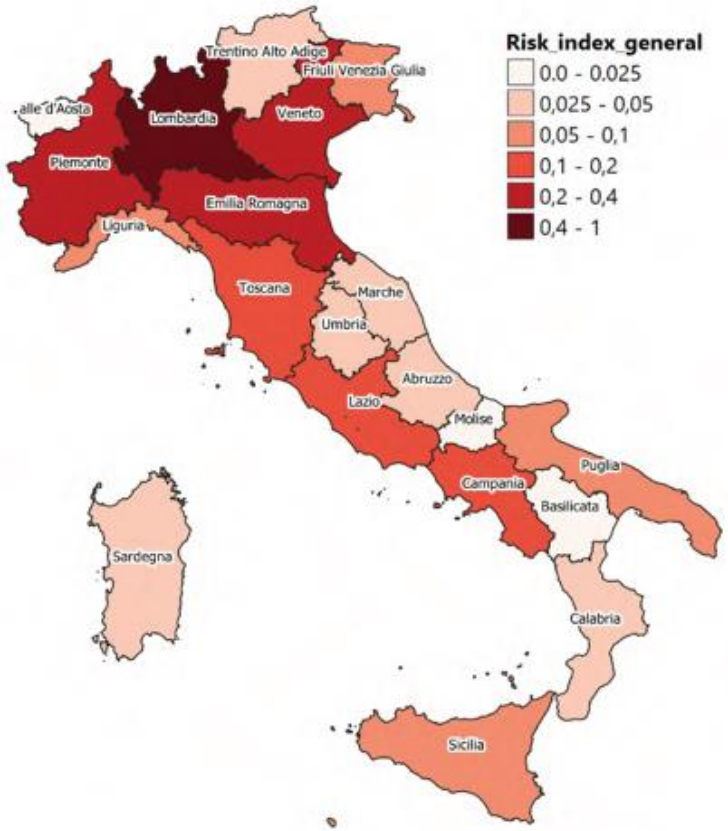

Likelihood of being infected once exposed

**AIR POLLUTION**
**AVERAGE WINTER TEMPERATURE**
**AGE OF POPULATION**

Measure of the resources exposed

**TOTAL POPULATION**

## A-PRIORI RISK MAP




**STATIC MODEL VS. DYNAMIC MODEL**

**Pluchino et al., 2021**

# Methodology


Multi-agent programming language for simulating and modelling complex systems (Wilensky, 1999)

# Agents setup

**Two type of agents**

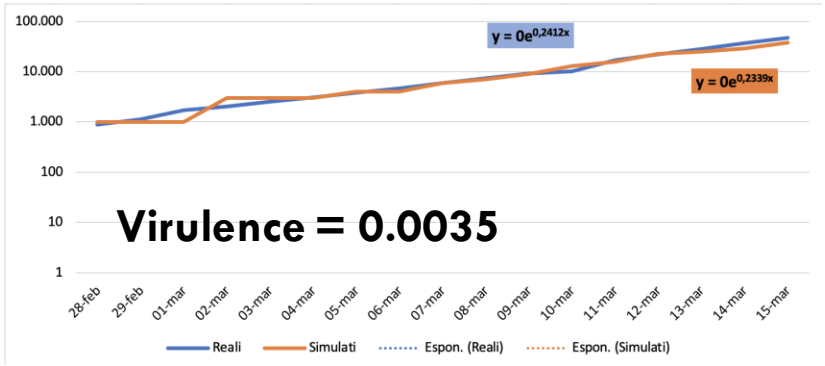
Regions

Individuals

**Scale 1:1000**

1 individual agent → 991 real individuals

# SIR Epidemic Dynamics


**Virulence = 0.0035**




**Hazard** = $\beta_1$ Housing Concentration + $\beta_2$ Healthcare Density

**Vulnerability** = $\alpha_1$ Average Winter Temperature + $\alpha_2$ Air Pollution

death-prob-over-60 = 0.95
death-prob-under-60 = 0.05

https://www.epicentro.iss.it/coronavirus/sars-cov-2-decessi-italia

lethality = Gaussian (0.022, 0.01)
Russell et al., 2020

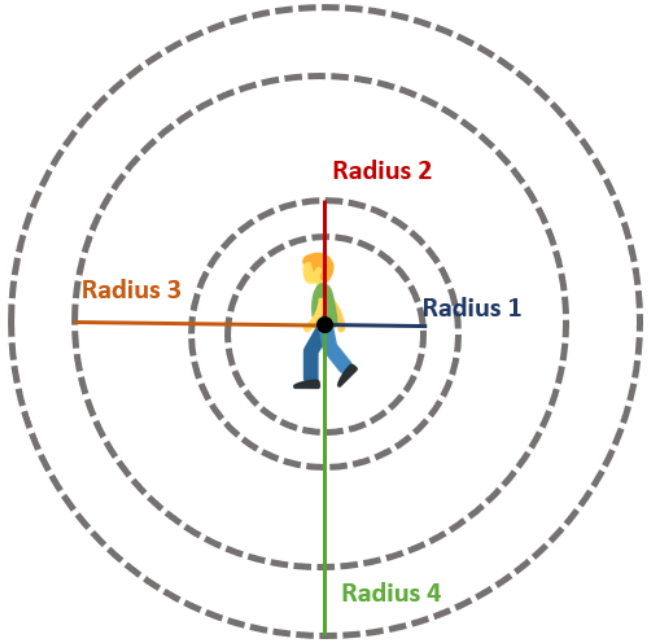
http://www.salute.gov.it/portale/nuovocoronavirus/dettaglioNotizieNuovoCoronavirus.jsp?lingua=italiano&id=5117

# Implementation of mobility restrictions

## MOBILITY DYNAMICS

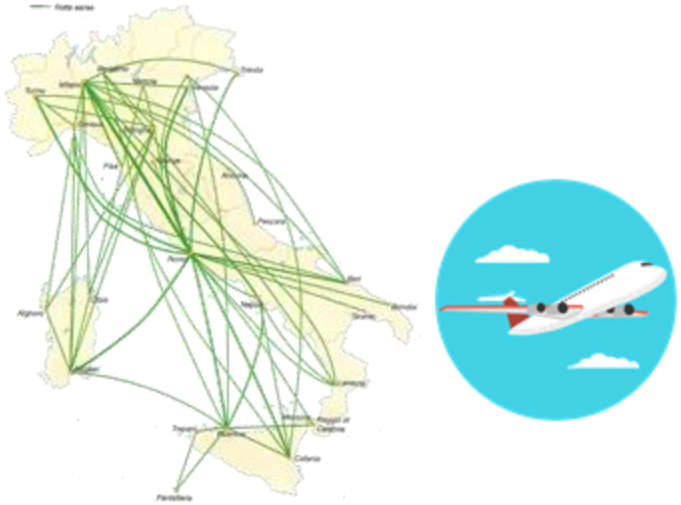
Under-60 → 9/10
Over-60 → 4/5

- Radius 1 = 2 km · Mobility Index
- Radius 2 = 8 km · Mobility Index
- Radius 3 = 40 km · Mobility Index
- Radius 4 = 50 km · Mobility Index




Under-60 → 1/10
Over-60 → 1/5

- Make a trip by plane





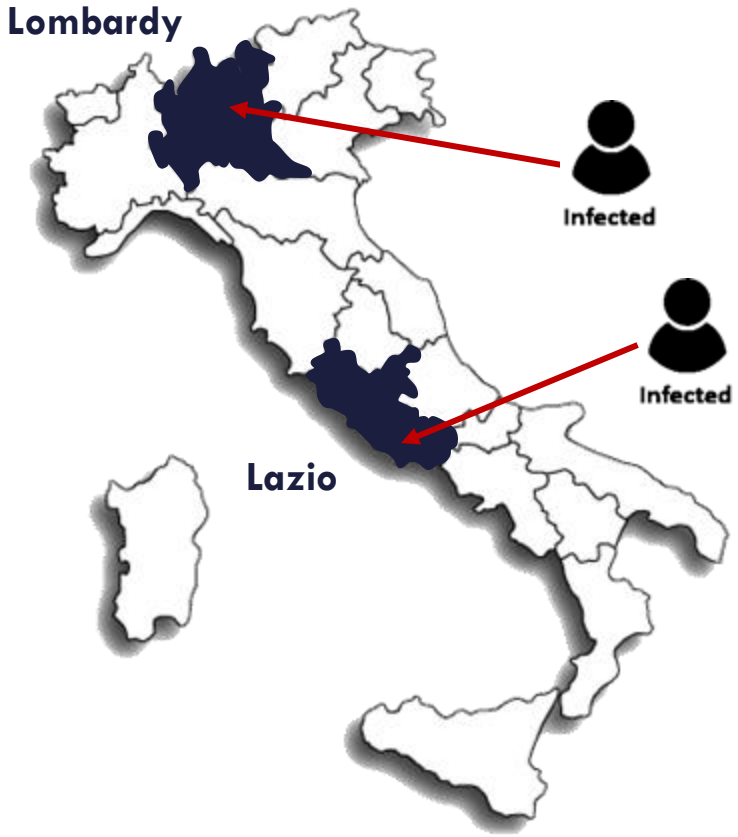
**Mobility data: 7th March, 2020 – 25th June, 2020**

- Reduction in percentage of air flights[1]
- Reduction of the dimension of the mobility radius[2]
- Reduction of the number of trips[3]

[1]https://www.eurocontrol.int/Economics/DailyTrafficVariation-States.html
[2]https://covid19mm.github.io/in-progress/2020/03/13/first-report-assessment.html
[3]https://www.google.com/covid19/mobility/

# Simulations: initial conditions

| Preliminary Simulations | Starting date | Final date | Lethality | Virulence |
|---|---|---|---|---|
| 1 | 07/09/2019 | 25/06/2020 | 0,022 | 0,0035 |
| 2 | 21/09/2019 | | | |
| 3 | 14/12/2019 | | | |
| 4 | 28/12/2019 | | | |
| 5 | 11/01/2020 | | | |
| 6 | 25/01/2020 | | | |
| 7 | 08/02/2020 | | | |
| 8 | 22/02/2020 | | | |




*Original Research Article*

**Unexpected detection of SARS-CoV-2 antibodies in the prepandemic period in Italy**

Giovanni Apolone[1]*, Emanuele Montomoli[2,3]*, Alessandro Manenti[3,4], Mattia Boeri[1], Federica Sabia[1], Inesa Hyseni[4], Livia Mazzini[2,4], Donata Martinuzzi[4], Laura Cantone[5], Gianluca Milanese[6], Stefano Sestini[1], Paola Suatoni[1], Alfonso Marchianò[1], Valentina Bollati[5], Gabriella Sozzi[1] and Ugo Pastorino[1]

**SARS-CoV-2 seroprevalence trends in healthy blood donors during the COVID-19 Milan outbreak**

Luca Valenti, MD[1,2*], Annalisa Bergna, BS[3,4*], Serena Pelusi, MD[1,2], Federica Facciotti, PhD[5], Alessia Lai, BS, PhD[3,4], Maciej Tarkowski, BS, PhD[3,4], Alessandra Berzuini, MD[2], Flavio Caprioli, MD, PhD[1,6], Luigi Santoro, MSc[2], Guido Baselli, PhD[2], Carla della Ventura, BS[3,4], Elisa Erba, MSc[2], Silvano Bosari, MD, PhD[1,7], Massimo Galli, MD[3,4], Gianguglielmo Zehender, BS, PhD[3,4*], Daniele Prati, MD[2*°].

**One in 20 Milanese was already positive before February**

*CRONACA* 20/05/2020 14:38 CEST

**"Un milanese su 20 era già positivo prima di febbraio"**

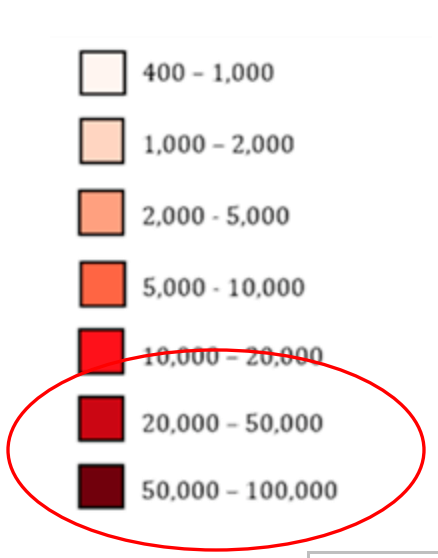
Il risultato di uno studio del Policlinico di Milano sui donatori di sangue pubblicato in anteprima (pre-print) su medRxiv

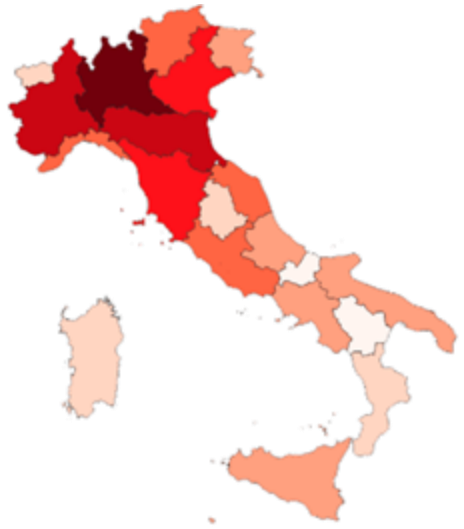
HuffPost

Source: https://www.huffingtonpost.it/entry/un-milanese-su-20-era-gia-positivoprima-di-febbraio_it_5ec5221ac5b61e26b0d9f101

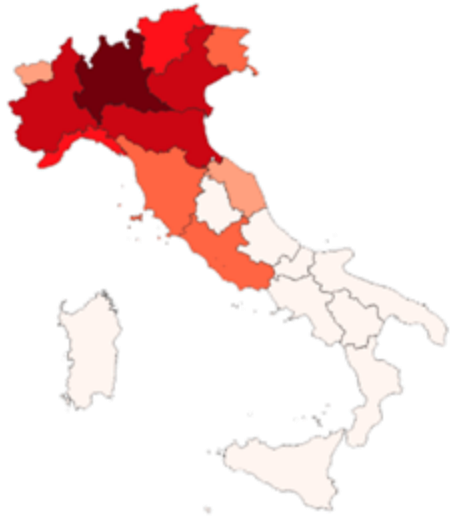
# Results for the Status Quo with Total Lockdown

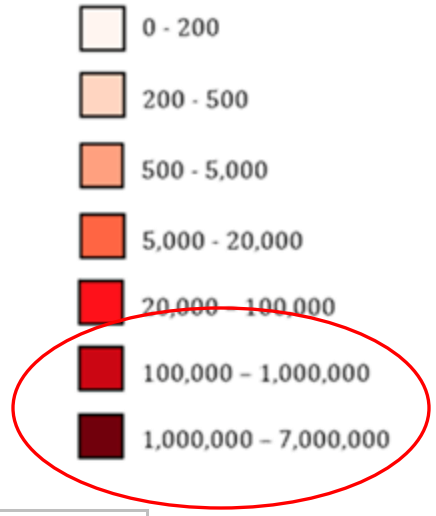
**INFECTED –** REAL DATA



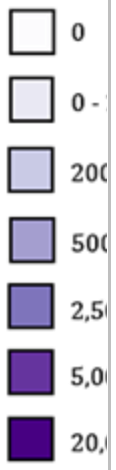



**INFECTED –** SIMULATED STATUS QUO (SQ)






**DEA** … **QUO**






## WHO: 10% of world's people may have been infected with virus

By JAMEY KEATEN October 5, 2020

GENEVA (AP) — The head of emergencies at the World Health Organization said Monday the agency's "best estimates" indicate roughly 1 in 10 people worldwide may have been infected by the coronavirus — more than 20 times the number of confirmed cases — and warned of a difficult period ahead.

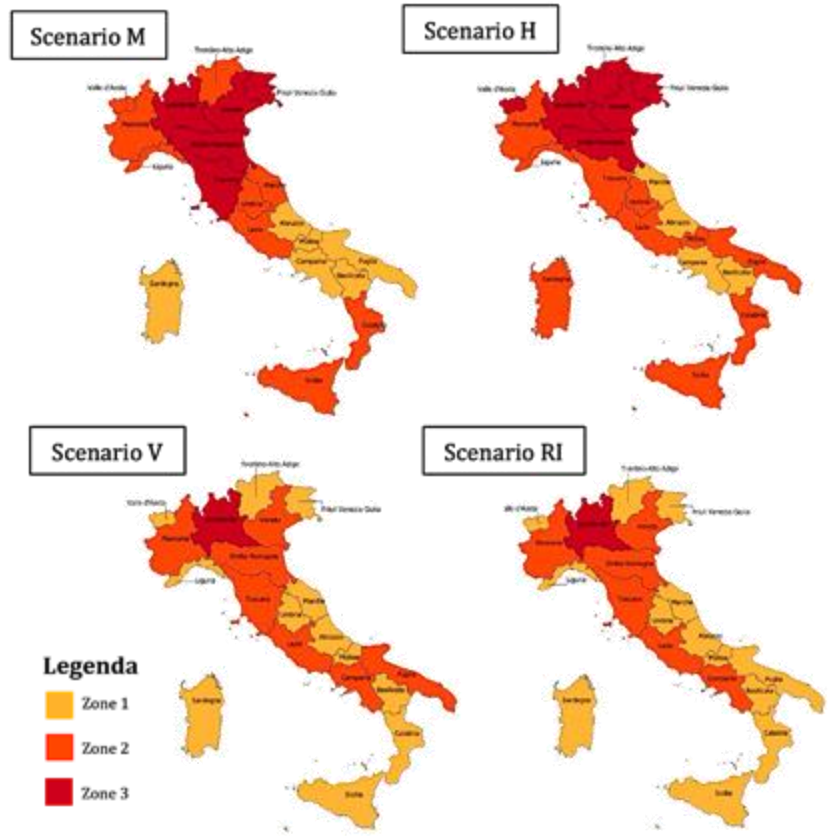
Dr. Michael Ryan, speaking to a special session of the WHO's 34-member executive board focusing on COVID-19, said the figures vary from urban to rural areas, and between different groups, but that ultimately it means "the vast majority of the world remains at risk." He said the pandemic would continue to evolve, but that tools exist to suppress transmission and save lives.

Source: https://apnews.com/article/virus-outbreak-archive-united-nations-54a3a5869c9ae4ee623497691e796083

# Simulations with Differentiated Restrictions

| Risk index zone | Parameter | ZONE 1 | ZONE 2 | ZONE 3 |
|---|---|---|---|---|
| Scenario M | mobility index | No mobility restriction | 50% of mobility restriction | Total mobility restriction |
| Scenario H | hazard | | | |
| Scenario V | vulnerability | | | |
| Scenario RI | risk index | | | |

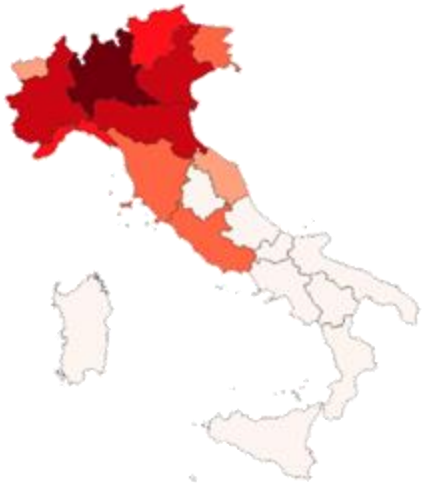
| Regions | mobility index | Zone | hazard | Zone | vulnerability | zone | risk index | Zone |
|---|---|---|---|---|---|---|---|---|
| Abruzzo | 0,15 | 1 | 0,33 | 1 | 0,06 | 1 | 0,04 | 1 |
| Basilicata | 0,03 | 1 | 0,23 | 1 | 0,01 | 1 | 0,01 | 1 |
| Calabria | 0,37 | 2 | 0,37 | 2 | 0,05 | 1 | 0,03 | 1 |
| Campania | 0,24 | 1 | 0,26 | 1 | 0,25 | 2 | 0,11 | 2 |
| Emilia Romagna | 0,81 | 3 | 0,69 | 3 | 0,23 | 2 | 0,27 | 2 |
| Friuli Venezia Giulia | 0,81 | 3 | 0,77 | 3 | 0,07 | 1 | 0,09 | 1 |
| Lazio | 0,53 | 2 | 0,50 | 2 | 0,23 | 2 | 0,19 | 2 |
| Liguria | 0,48 | 2 | 0,58 | 2 | 0,08 | 1 | 0,08 | 1 |
| Lombardia | 1,00 | 3 | 0,94 | 3 | 0,62 | 3 | 1,00 | 3 |
| Marche | 0,60 | 2 | 0,33 | 1 | 0,07 | 1 | 0,04 | 1 |
| Molise | 0,00 | 1 | 0,44 | 2 | 0,01 | 1 | 0,01 | 1 |
| Piemonte | 0,59 | 2 | 0,58 | 2 | 0,29 | 2 | 0,29 | 2 |
| Puglia | 0,29 | 1 | 0,45 | 2 | 0,11 | 2 | 0,09 | 1 |
| Sardegna | 0,29 | 1 | 0,60 | 2 | 0,04 | 1 | 0,04 | 1 |
| Sicilia | 0,54 | 2 | 0,53 | 2 | 0,09 | 1 | 0,08 | 1 |
| Toscana | 0,74 | 3 | 0,46 | 2 | 0,17 | 2 | 0,14 | 2 |
| Trentino Alto Adige | 0,66 | 2 | 0,74 | 3 | 0,04 | 1 | 0,05 | 1 |
| Umbria | 0,55 | 2 | 0,42 | 2 | 0,04 | 1 | 0,03 | 1 |
| Valle d'Aosta | 0,64 | 2 | 0,73 | 3 | 0,01 | 1 | 0,01 | 1 |
| Veneto | 0,95 | 3 | 0,69 | 3 | 0,27 | 2 | 0,32 | 2 |




Pluchino et al., 2021

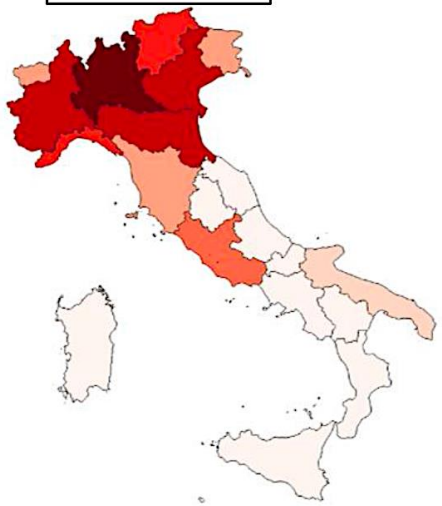
# Simulations with Differentiated Restrictions

**INFECTED –** STATUS QUO (SQ)

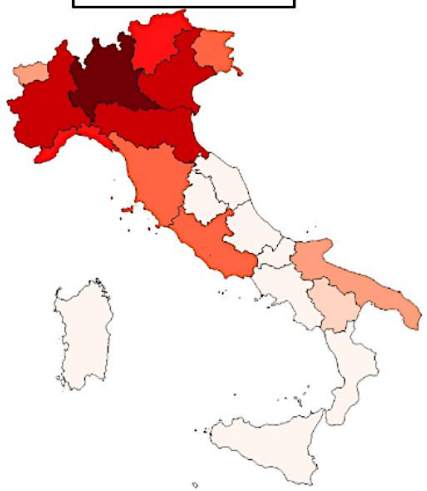


| SCENARIO | Number of region for each zone | | | % increment of infected with respect to Status Quo | |
|---|---|---|---|---|---|
| | Zone 1 | Zone 2 | Zone 3 | Total | Lombardy |
| M | 6 | 9 | 5 | +22% | **+30%** |
| H | 4 | **10** | 6 | +17% | +25% |
| V | 12 | 7 | 1 | +22% | **+30%** |
| RI | 13 | 6 | 1 | +21% | +28% |

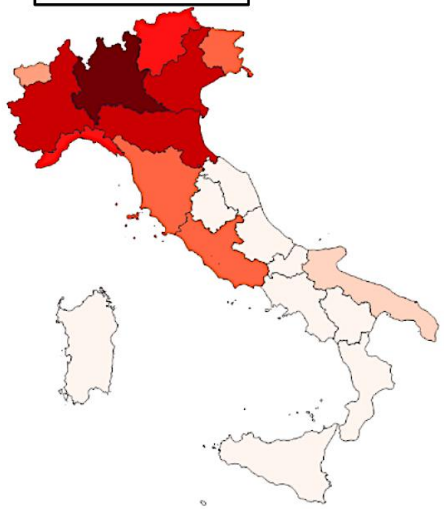
Scenario M



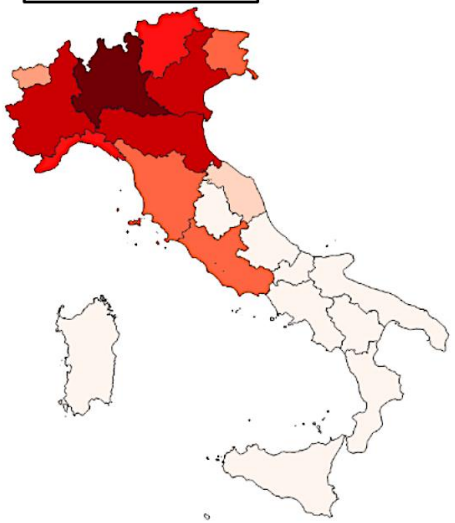
Scenario H



Scenario V



Scenario RI

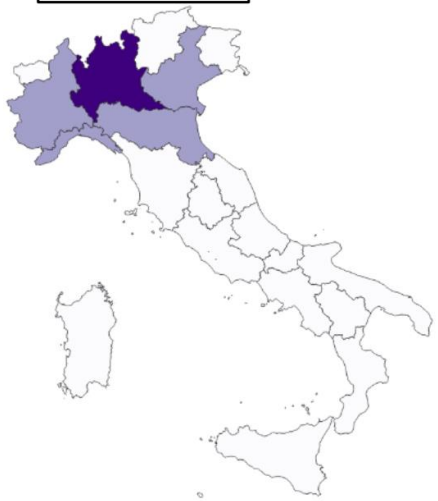


# Simulations with Differentiated Restrictions

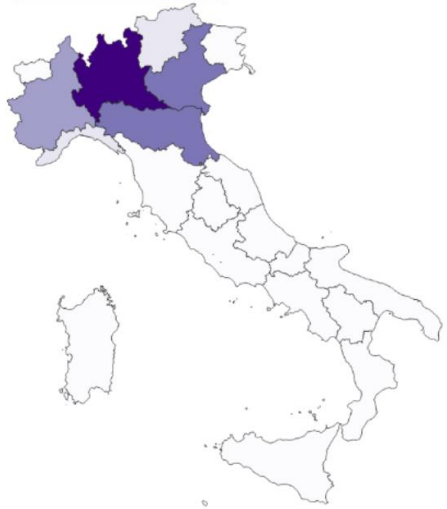
**DEATHS –** STATUS QUO (SQ)

| SCENARIO | Number of region for each zone | | | % increment of deaths with respect to Status Quo | |
|---|---|---|---|---|---|
| | Zone 1 | Zone 2 | Zone 3 | Total | Lombardy |
| M | 6 | 9 | 5 | +28% | **+31%** |
| H | 4 | **10** | 6 | +30% | +30% |
| V | 12 | 7 | 1 | +18% | +20% |
| RI | 13 | 6 | 1 | +26% | +30% |

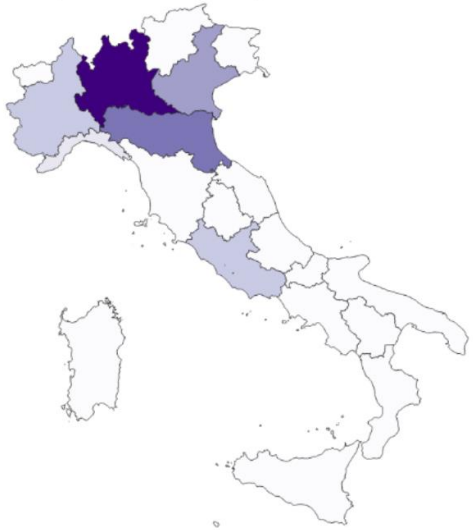
Scenario M



Scenario H



Scenario V



Scenario RI

# Conclusions

## Results:

- The model is capable of dynamic reproducing the impact of mobility restrictions on COVID-19 spreading in Italy
- The model allows to simulate different scenario beyond the *status quo* one
- Localized restrictions according to an *a-priori* risk index

## Next steps:

- Simulation of the second waves including new mobility restrictions imposed and vaccination



# THANKS FOR YOUR ATTENTION

e-mail: martina.fazio@phd.unict.it