Simulating the effects of mobility restrictions in the spread of SARS-CoV-2 in metropolitan areas

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16:30 - 17:30 EDT

[O10] Pandemic lock-downs in the city: capturing the effects of mobility restrictions

6th July 2021

Background

In Portugal, strict lockdown periods have been established since March 2020:

- limitations on inter-municipal flows
- suspension of all non-essential travel
- compulsory remote work

Simulations of daily new infections in metropolitan areas for different mobility scenarios, to test the potential effect of travel restrictions on virus dissemination.

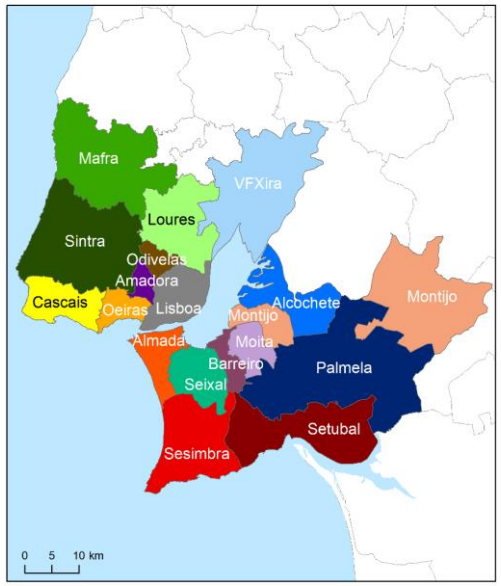
Metropolitan areas:

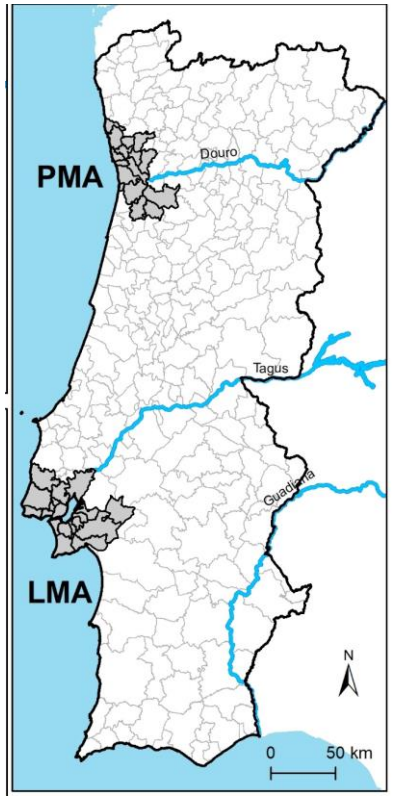
- the most densely populated areas in the country
- intense commuting flows
- virus dissemination across municipalities

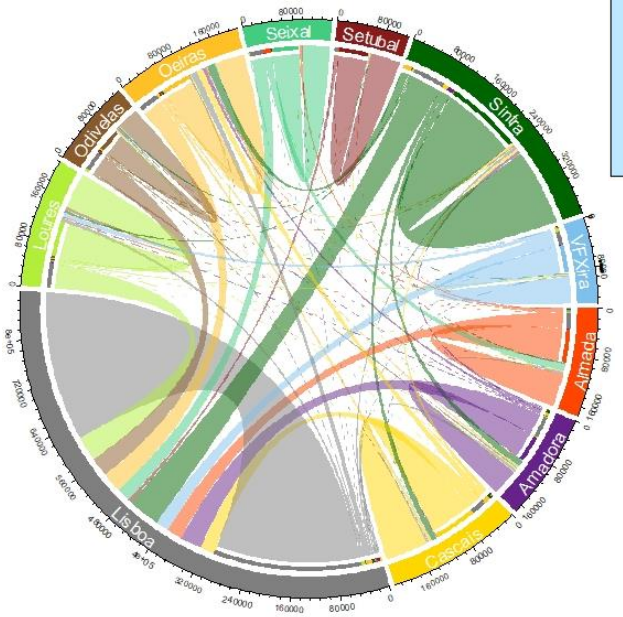
Study area

Lisbon (LMA)

- 18 municipalities
- 3015 km^2
- 2 840 005 inhabitants (28%)
- 81% of commuters
- 16% public transport

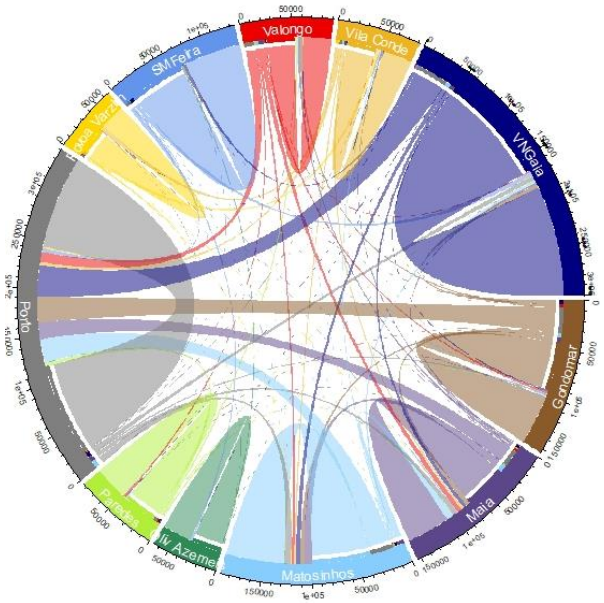




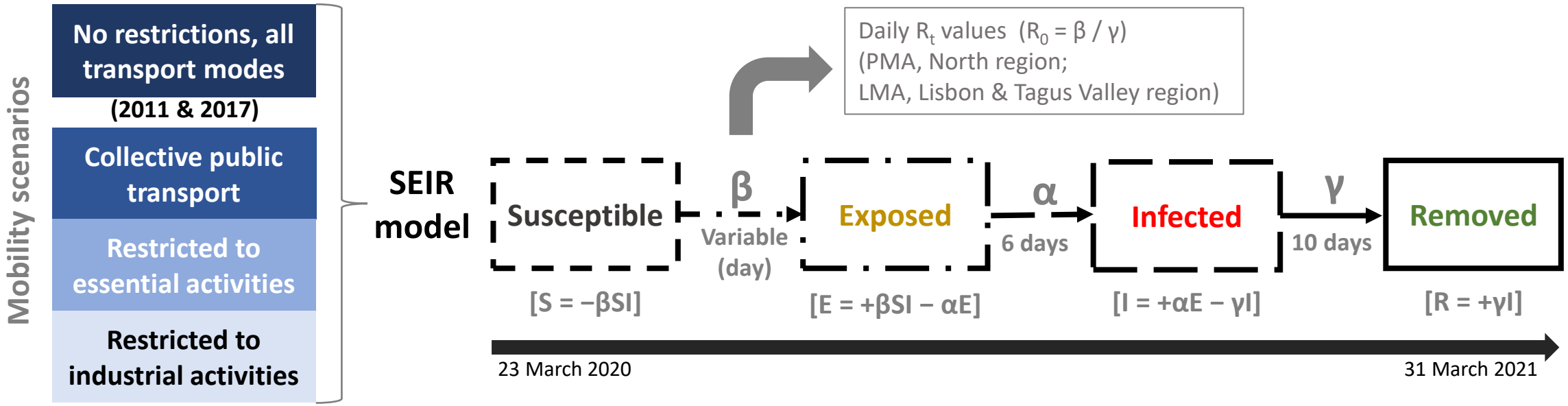


Porto (PMA)

- 17 municipalities
- 2041 km^2
- 1 721 038 inhabitants (17%)
- 79% of commuters
- 11% public transport



Mobility scenarios & SEIR model



Daily new cases. Active cases per day. Virus spread over time. Relation with mobility flows and restrictions.

Based on the regulations implemented by the Portuguese government, **essential sectors** are:

- ✓ Agriculture, fisheries, and forestry; extraction and transformation industry;
- ✓ electricity and gas supply; water supply, sanitation, and residues;
- ✓ construction; trade and auto repair;
- ✓ transport and storage;
- ✓ human health.

Mobility scenarios & SEIR model - *scripting*

All population is initially susceptible

First infections based on nr. cases PT 23/03

First exposed calculated with model

Update of SEIR matrix based on initial cases

```r
# set up SEIR matrix
SEIR <- matrix(nrow = locs_len, ncol = 4) # initiate an empty SEIR matrix
colnames(SEIR) <- c("S", "E", "I", "R") # rename the vectors
SEIR[, "S"] <- N_k # assign the number of successible people in each cell
SEIR[, "E"] <- 0 # assign the number of exposed people in each cell
SEIR[, "I"] <- 0 # assign the number of infected people in each cell
SEIR[, "R"] <- 0 # assign the number of recovered people in each cell

# first infection
# assume no all are infectious and no one in incubation period at the beginning
first_infections <- (pop_cases$origin == zone0_id) * zone0_infected
str(first_infections)
str(zone0_infected)

#Calculate first exposed based on sigma (rate exposed to infected=0.2) and first infections
first_exposed <- first_infections / sigma_vec
first_exposed

#Update the SEIR matrix with first infections and first exposed
#remove first infections and exposed from susceptible population
SEIR[, "S"] <- SEIR[, "S"] - (first_infections + first_exposed)
#add first infections to infected population
SEIR[, "I"] <- SEIR[, "I"] + first_infections
#add first exposed to exposed population
SEIR[, "E"] <- SEIR[, "E"] + first_exposed - first_infections
```

Mobility scenario to use (origin/destination matrix)

Calculation of new exposed based on OD matrix and nr. infected (within and outside municipality)

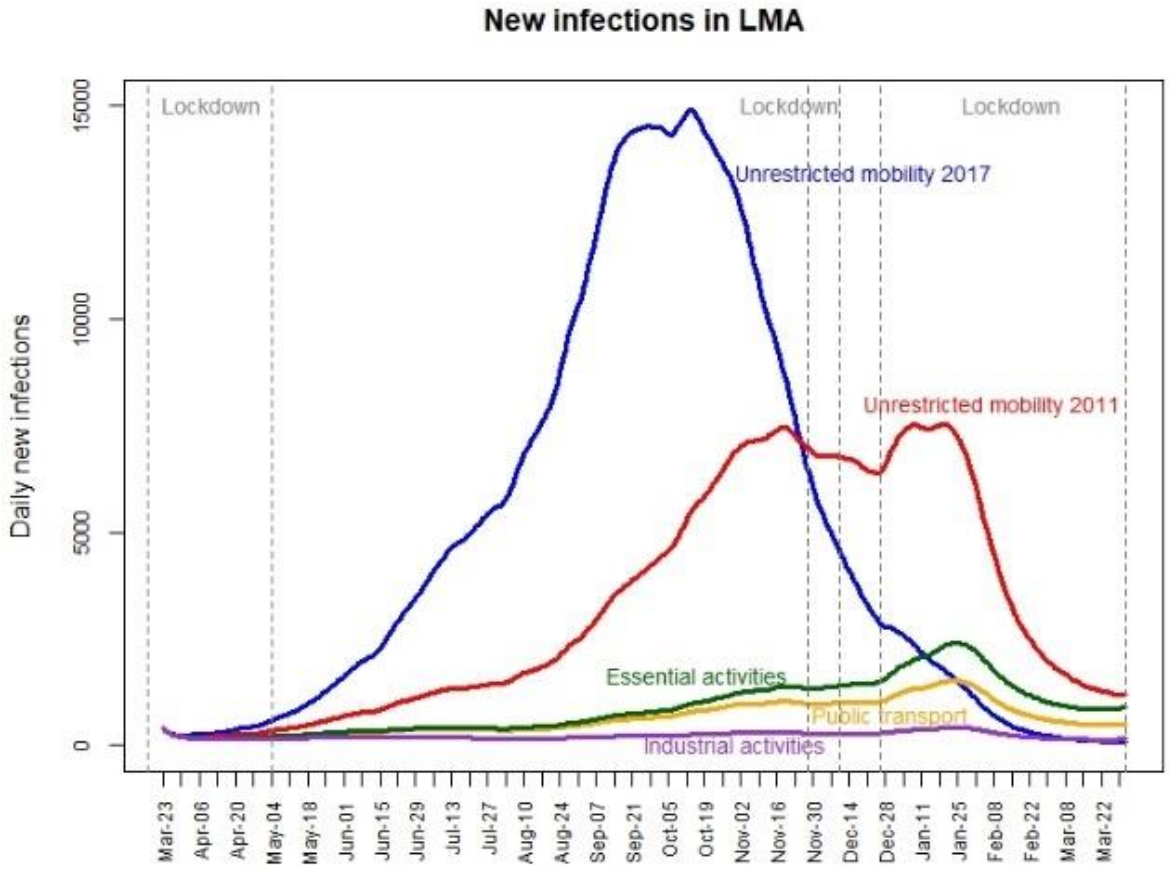
Calculation of new infected based on new exposed

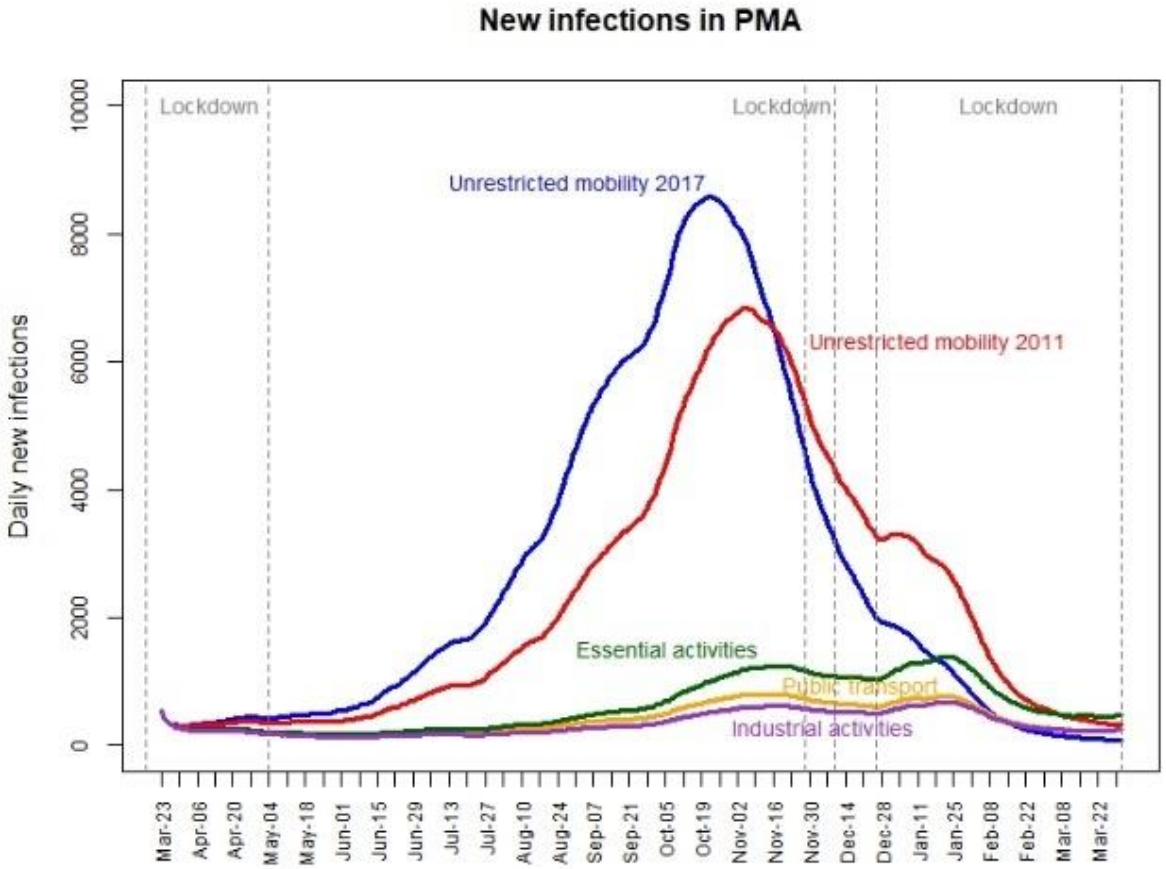
Calculation of new recovered based on new infected

Update of SEIR matrix, every day

```r
#Define OD to use
OD <- aml_all

# New E
infected_mat <- replicate(locs_len, SEIR_nsim[, "I"])
OD_all_infected <- round(aml_all*infected_mat)
flow_all_infected <- colSums(OD_all_infected)
total_flow_all_infected <- sum(flow_all_infected)
print(paste0("Total infected full flow: ", total_flow_all_infected))
new_exposed <-
  beta_vec * SEIR_sim[, "S"] * flow_all_infected / (N_k + colSums(aml_all)) + #exposed by contacting with imported infectious cases
  beta_vec * SEIR_sim[, "S"] * SEIR_sim[, "I"] / N_k #exposed by contacting with local infected cases
new_exposed[is.na(new_exposed)] <- 0
total_new_exposed <- round(sum(new_exposed))
print(paste0("New exposed: ", total_new_exposed))
new_exposed <- ifelse(new_exposed > SEIR_sim[, "S"], SEIR_sim[, "S"], new_exposed) #make sure the N exposed is not bigger than total susceptible

# New I
new_infected <- sigma_vec * SEIR_sim[, "E"]
total_new_infected <- round(sum(new_infected, na.rm = T))
print(paste0("New infected: ", total_new_infected))

# New R
new_recovered <- gamma_vec * SEIR_sim[, "I"]
total_new_recovered <- round(sum(new_recovered, na.rm = T))
print(paste0("New recovered: ", total_new_recovered))

SEIR_sim[, "S"] <- SEIR_sim[, "S"] - new_exposed
SEIR_sim[, "E"] <- SEIR_sim[, "E"] + new_exposed - new_infected
SEIR_sim[, "I"] <- SEIR_sim[, "I"] + new_infected - new_recovered
SEIR_sim[, "R"] <- SEIR_sim[, "R"] + new_recovered
SEIR_sim <- ifelse(SEIR_sim < 0, 0, SEIR_sim)
```

RESULTS - SEIR modeling by mobility scenario – daily new cases

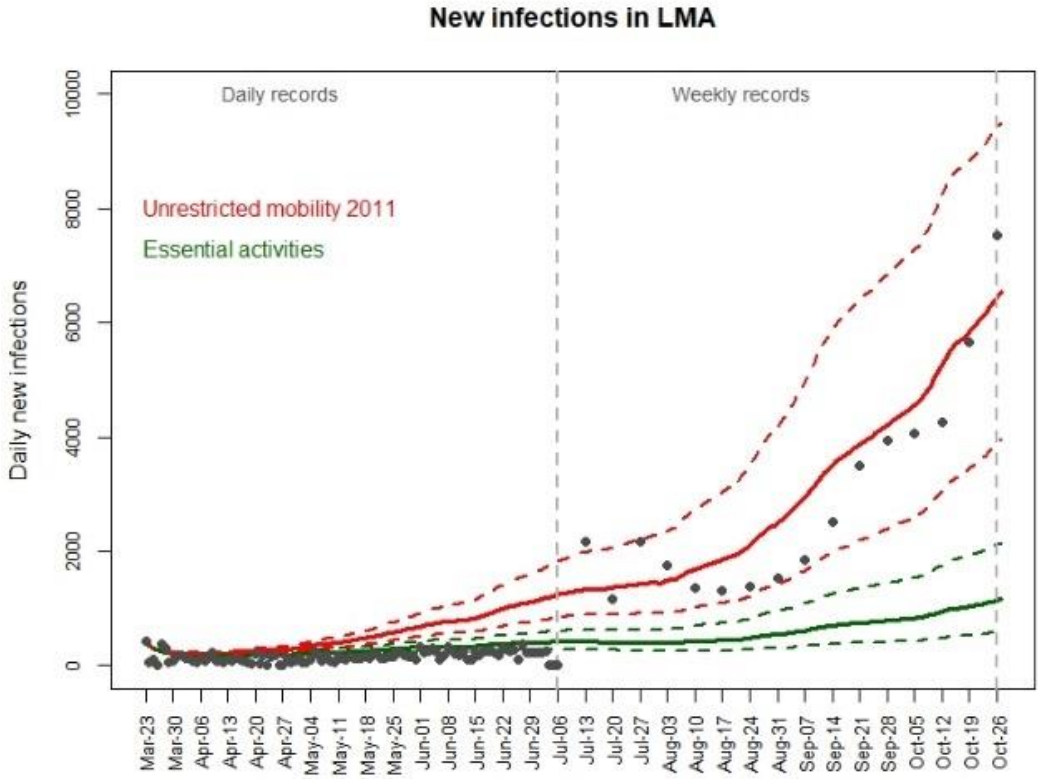


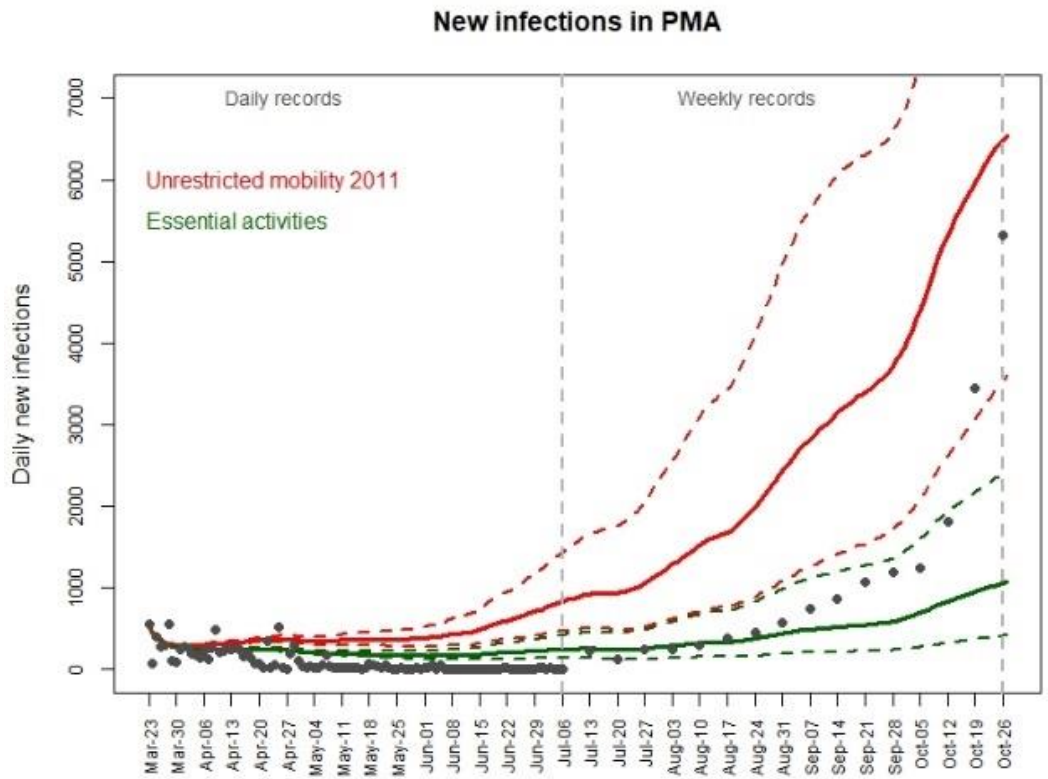


Stricter lockdown periods (vertical dashed lines) cover the periods between **23rd March and 4th May 2020**, **28th November to 8th December 2020**, and from **27th December 2020 until 31st March 2021**

RESULTS - SEIR modeling by mobility scenario – official records

- ✓ Daily new cases - Estimations *vs* oficial records (23 March 2020 to 26 October 2020)
- ✓ 2 scenarios: Unrestricted mobility & Restricted to Essential activities

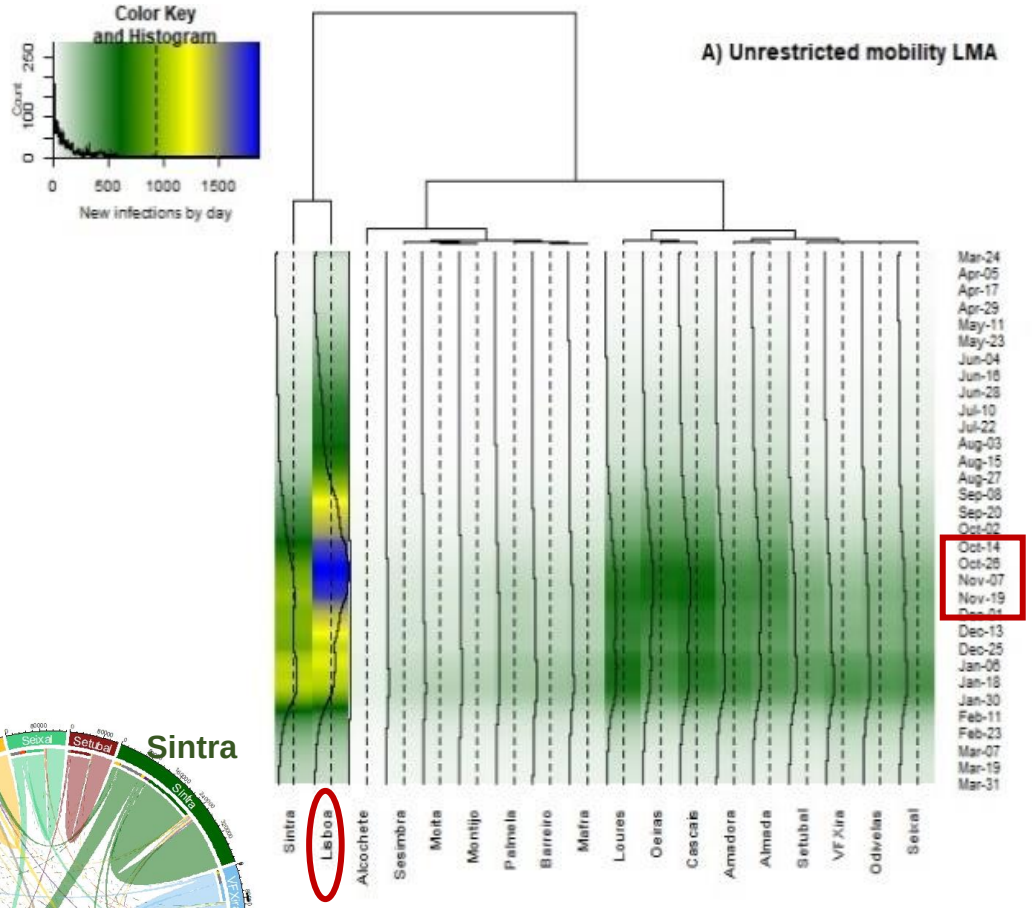


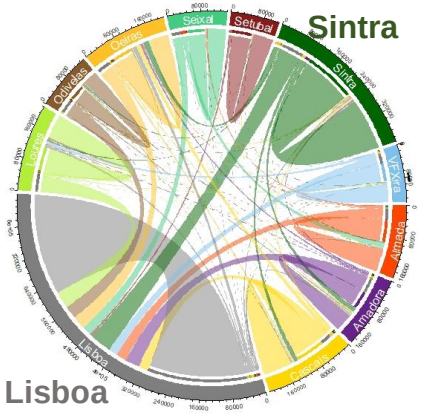


Estimated values considering the upper and lower thresholds of the confidence interval (95%) of R_t (dashed lines).
Official recorded cases of new infections are represented as points, daily values until the 6th July, and cumulative weekly values afterwards.

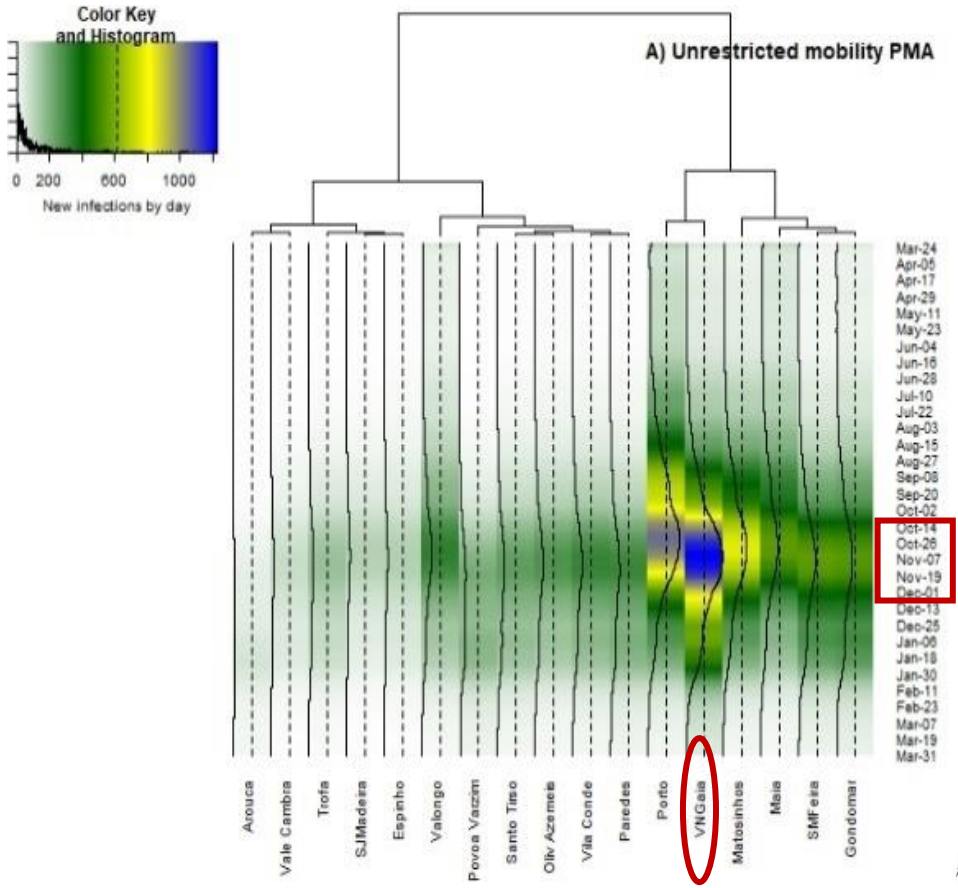
RESULTS - Time-series clustering with dynamic time-warping

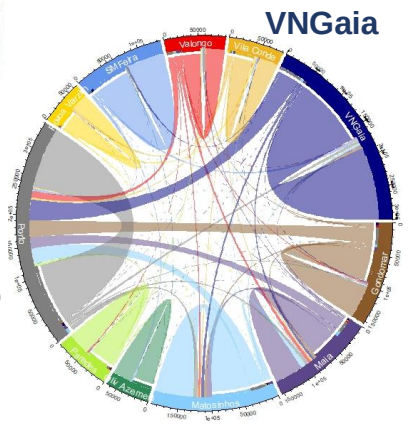
Lisbon (LMA)





Porto (PMA)





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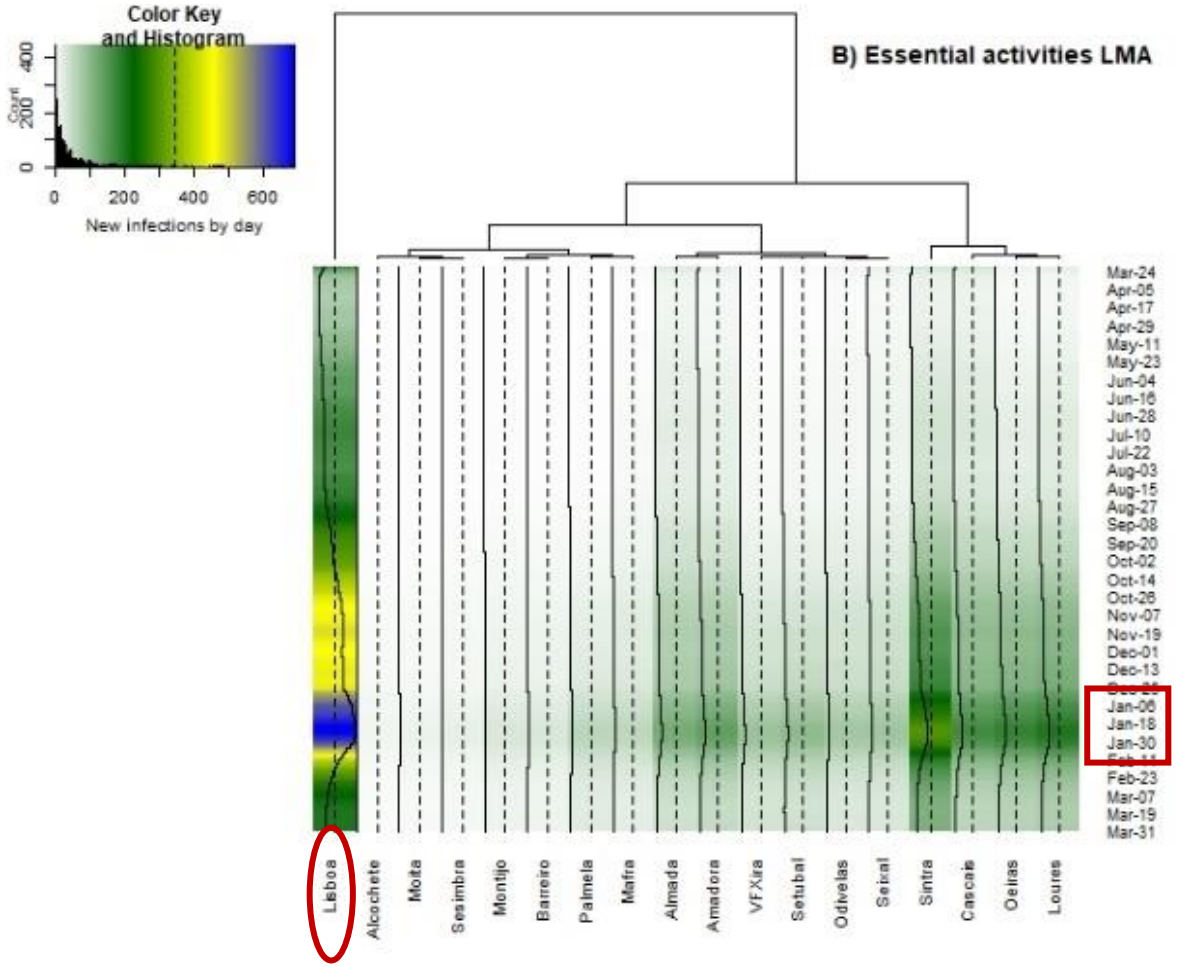

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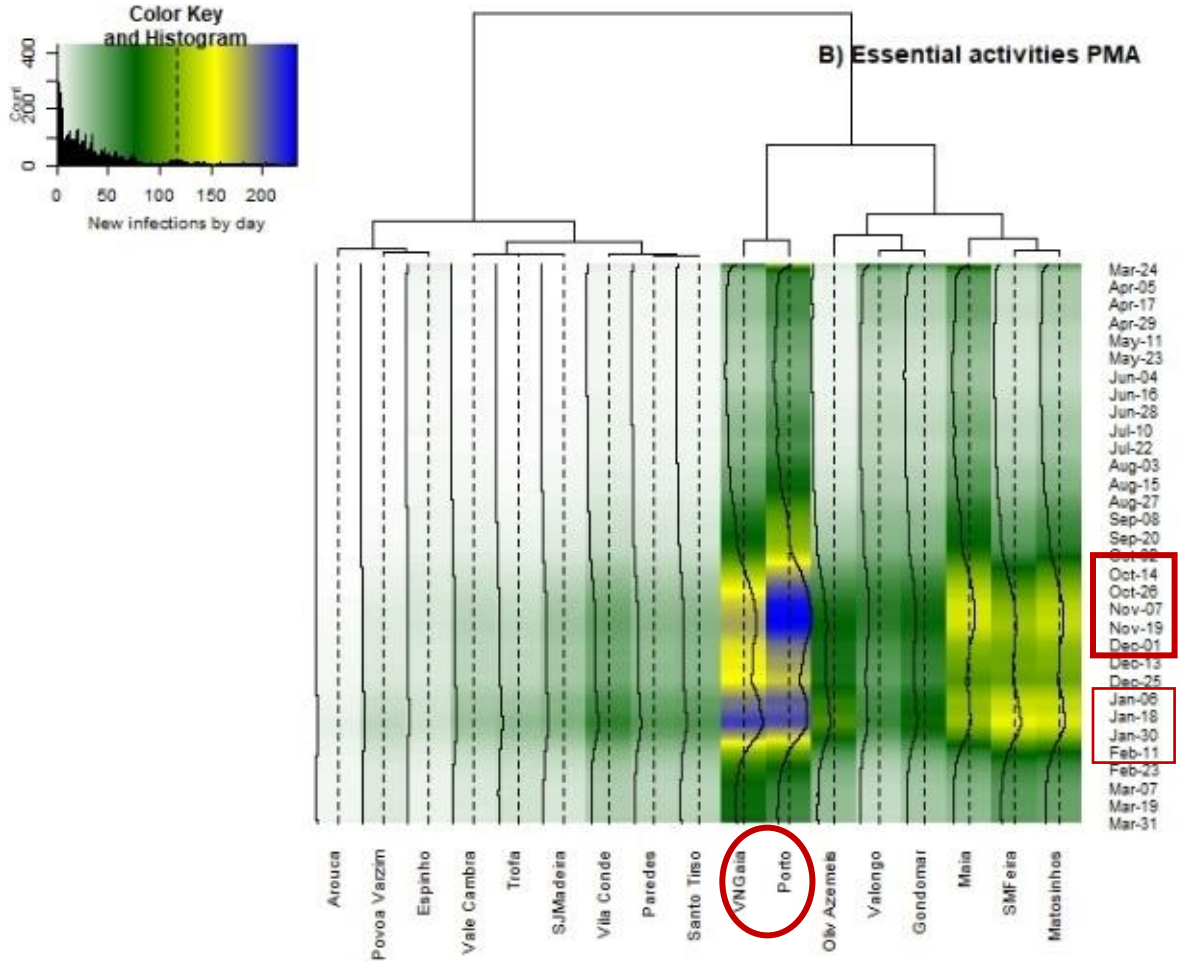

Conclusions

- ✓ The spread of the virus has responded to the mobility restrictions implemented. The number of new infections decreases after lockdown periods, with a certain delay

- ✓ Timeline of virus spread differs among metropolitan areas. PMA, closer to the scenario of mobility restricted to essential activities, in LMA closer to the unrestricted mobility scenario (lower threshold). Linked to secondary outbreaks in July 2020, especially in LMA, likely due to the ease of restrictions

- ✓ After Christmas, there was a substantial increase in the number of infected cases and fatalities, and the capacity of the health system was challenged. New infections started to decrease in mid-January 2021, following the implementation of mobility and social restrictions. Trends are captured by the simulations.

- ✓ In LMA, Lisbon absorbs most of the flows regardless of the scenario considered, higher number of cases. In PMA, Porto and VNGaia share the highest number of cases, depending on the scenario.

- ✓ **Further work:** How these restrictions can be adjusted to define suitable reopening strategies;
  how other social distancing and hygiene measures can be of complement;
  how the mobility conditions in metropolitan areas can be improved beyond the pandemic.

Thank you!

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