An Epidemic Mobility Model with Symptomatic and Asymptomatic Individuals Allowing Variation of Contact Rates Between Individuals and Across Regions

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INTRODUCTION

- Accounting for geographical mobility and asymptomatic individuals to understand the effects of lacking control on asymptomatic infected individuals spreading the virus across regions.
- We investigate when does connection among regions nullify the gains of major contact restrictions in a big city.
- We develop a composite model and run multiple simulations only varying the contact rates of individuals and the mobility patterns while holding everything else constant. By observing the differences in key outcome indicators of disease dynamics between these simulations, we assess the overall impacts from variation in contact rates and mobility patterns.

METHODS

- Modified SIR model using system of ODEs.
- SAIRD model – Susceptible, Asymptomatic able to transmit disease, Infected and Symptomatic, Recovered, Dead.
- Regional Mobility *(Sattenspiel and Dietz 1995)* – 3 regions, each with resident SAIRD traveling (S_{ik},I_{ik},etc.) and non-traveling populations (S_{ii},I_{ii},etc.).
- We use two established, common 3-regional relationships *(Sattenspiel et al. 2000)*:
  I. Central Marketplace - one of the communities is the main focus of between-group activities for both satellite communities.
  II. Sister-Towns – there is a regional center, but also significant amount of interaction between the two satellites.
- Resident population of Region 1 is 2.5 times that of Regions 2&3.

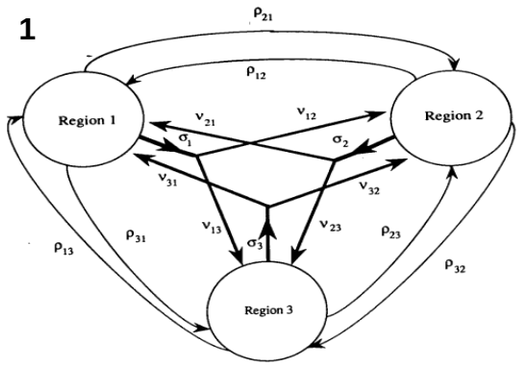


Figure 1. Diagram of regional mobility process incorporated in the model with the indexed parameters ρ_{ik}, σ_{ik}, ν_{ik}.

ρ_{ik} - return rate from region k to region i
σ_{ik} - rate residents of i leave on trips to k
ν_{ik} - probability when resident of i takes trip, it stops in k

Central Marketplace - 2a

Sister-Town - 2b

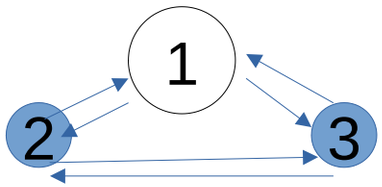


Figure 2a. Schematic of the Central Marketplace regional relationship used. **Figure 2b.** Schematic of the Sister-Town regional relationship used.

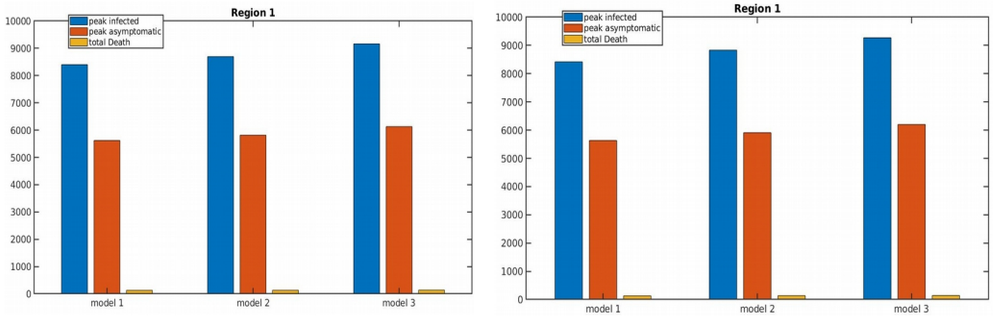
CONTACT RATES

- The contact rates with susceptible individuals can be different across regions for asymptomatic and symptomatic individuals κ_i^A, κ_i^I.
- By carefully choosing sets of contact rates we can model common situations like symptomatic people are more likely to quarantine, or one region having strict social distancing while its surrounding regions do not. Monitoring the course of the population curves gives a good idea of disease dynamics.

RESULTS

- We model the Sister-Town/Central Marketplace Scenario three times with three different sets of contact rates and compare the simulation outcomes. The different contact rates represent levels of "strictness" in the regions.
- Model 1 $\kappa_i^A=[7,7,7]\,\kappa_i^I=[7,7,7]$ contact rates are low for symptomatic & asymptomatic in all regions.
- Model 2 $\kappa_i^A=[7,20,20]\,\kappa_i^I=[7,7,7]$ in regions 2&3 asymptomatic individuals contact others at a high rate.
- Model 3 $\kappa_i^A=[7,20,20]\,\kappa_i^A=[7,20,20]$ region 1 has contact restrictions, regions 2&3 do not.

Central Marketplace (CMS) - 3a **Sister-Town (STS) - 3b**



Figures 3a, 3b. Snapshot of disease dynamics across models represented as Peak Infected (PI), Peak Asymptomatic (PA) and Total Dead (TD), individuals over the 60 day simulations of the CMS **(3a)** and STS **(3b).**

STS

Model	PI	PA	TD
1	8417	5633	130
2	8833	5910	135
3	9272	6200	139

CMS

Model	PI	PA	TD
1	8401	5623	130
2	8696	5818	133
3	9164	6129	136

DISCUSSION

- For all models 1-3, the STS caused more infections and deaths compared to the CMS meaning interaction between the satellite regions caused increased spread of the disease.
- Model 1 has only low contact rates so its outcomes provide a benchmark for disease dynamics.
- Model 2 increases contact rates for asymptomatic individuals **only** in satellite regions 2 & 3.
  STS: 416 increase PI (4.9%), 273 increase PA (4.8%), and 5 more TD (3.8%) in region 1 compared to the benchmark.
  CMS: 285 increase PI (3.4%), 195 increase PA (3.5%), and 3 more TD (2.3%) in region 1 compared to the benchmark.
- Model 3 has very high contact rates for asymptomatic **and** symptomatic people in regions 2 & 3.
  STS: 855 increase PI (10.2%), 567 increase PA (10.1%), and 9 more TD (6.9%) in region 1 compared to the benchmark.
  CMS: 763 increase PI (9.1%), 506 increase PA (9.0%), and 6 more TD (4.6%) in region 1 compared to the benchmark.

CONCLUSION

- Only having unrestricted asymptomatic individuals in satellite regions like model 2 can cause a moderate rise in disease invasion of region 1. No restrictions for both asymptomatic and symptomatic individuals in satellite regions increases the severity of the disease dynamics in region 1 significantly.
- If we are trying to eradicate Covid-19, quarantining asymptomatic people is almost equally as crucial as symptomatic people.

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