Modelling COVID-19 in Refugee Settlements

Providing a safe environment to explore implications of policies to control the spread of COVID-19 in a refugee settlement

TU Delft

Overview

Modelling COVID-19 in Refugee Settlements

- Research Objectives
- Approach
- Simulation Summary
- Model Cards
- Results
- Team

TU Delft

Research Objectives

Modelling COVID-19 in

Refugee Settlements

Research Objective

Modelling COVID-19 in Refugee Settlements

Understand the driving factors of COVID-19 spread in refugee settlements and the impact of preventive and mitigative measures for response planning in these settlements

TU Delft

Research Objectives

1. Gain understanding about the spread of COVID-19 through daily activities in refugee settlements
    a. Understand the mechanisms behind the spread of COVID-19 in refugee settlements;
    b. Understand the impact of preventive and mitigating measures on the spread of COVID-19;
    c. Develop recommendations on the effect of preventive measures in relation to the required COVID-19 treatment capacity in refugee settlements;

2. Prove the usability of agent-based modeling as a tool in humanitarian response studies
    a. Develop an ABM to study the spread of an infectious disease using a bottom-up approach;
    b. Develop recommendations for further use of ABM to understand the results of human (inter)action within a refugee settlement

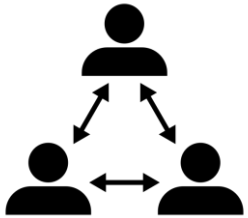
TU Delft

Approach

Modelling COVID-19 in Refugee Settlements

Agent Based Modeling

- Agent-based models facilitate a bottom-up approach, by studying emerging patterns, which are the result of actions and interactions of agents in the modelled environment;
- The actions and interactions are defined by a set of behaviour rules;
- Uncertainty is added to the model using randomized input numbers



TU Delft

Simulating the spread of COVID-19

- The ABM provides the means to simulate and analyse:
  - the spread of COVID-19 through a refugee settlement;
  - the impact of different preventive or mitigating measures, ranging from lockdowns to the construction of extra health care units;
  - the consequences of uncertainty regarding the behaviour and compliance for the refugees in the settlement.

TU Delft

Agent Based Modeling

- In agent-based models (ABMs), a set of behaviour rules defines the actions and interactions of agents in the modelled environment. This makes it possible to study how COVID-19 spreads as a function of the defined behaviour of individuals and households in refugee settlements;
- This approach also provides a systematic way to simulate and analyse the impact of different preventive or mitigating measures, ranging from lockdowns to the construction of extra health care units. The effect is analysed for uncertainty regarding the behaviour and compliance for the refugees in the settlement.

TU Delft

Modelled Environment

- The environment in which the simulation experiments are run resembles a prototypical refugee settlement;
- This environment is set up on the basis of generic characteristics of major refugee settlements (i.e. Za'atari, Bidi Bidi, Cox's Bazaar, Kakuma and Moria), taking into consideration factors such as topography and demographics;
- Throughout the experiments, the environment is set up randomly to account for differing settlements.

Data collection (settlements)

- The key demographics and topography for the modelled settlements (i.a. shelter locations and facilities [type, number, capacity]) are based on a review of available documents on key refugee settlements;
- This data is verified and complemented via interviews to gain more granular and updated insights on:
  - the camp composition and demographics, including shelter sizes and distribution of composition of households;
  - behaviour of camp inhabitants, including access to aid distribution mechanisms and facilities;
  - considered interventions (i.e. preventive and mitigative measures), including their prioritization.

TU Delft

Data collection (COVID-19)

- Distribution of infectiousness and disease progression (stages) is based on most recent findings in scientific researches and recommendations from public organizations;
- Existing uncertainty about epidemiological factors of COVID-19 is incorporated using random distributions that can be varied throughout the experiments;
- Age is an important determinant in the infectiousness of COVID-19, hence different distributions are distinguished for the following groups:
  - children (< 18 years)
  - adults (18 - 59 years)
  - elderly (60 < years)
- The epidemiologic factors are reviewed through interviews with experts.

Experimentation & Analysis

- The modelled environment simulates the spread of COVID-19 as well as the effect of different policy options, i.e. preventive and mitigating measures;
- The model results are analyzed using key performance indicators (KPIs), relating to the spread of the disease, especially among the most vulnerable groups, and health care capacity;
- Systematic simulation of a large set of scenarios (incl. different set-ups of the modelled environment) allows us to explore the impact of key behavioural patterns and the implications of different policies;
- The model results are validated and should be discussed with experts before developing recommendations for optimisation of considered policy options.

TU Delft

Simulation Summary

Modelling COVID-19 in

Refugee Settlements

TU Delft

Simulation Summary (1)

- Simulation of a generic refugee settlement with 240 households;
- On a regular basis, refugees move around the camp to:
  - obtain food;
  - obtain water;
  - use latrines;
  - consult health care;
- COVID-19 transmissions can occur when refugees are in close proximity (i.e. within 1.5m distance) of infected people.

Simulation Summary (2)

- Policy measures can be applied aiming to limit the spread of COVID-19 in the settlement, such as;
  - Restrict the movement of infected or vulnerable people;
  - Intensify social distancing;
  - Require wearing masks
- The effect of different policies can be measured in terms of:
  - Basic reproduction number (R0);
  - Daily number of infections;
  - Used capacity of COVID-19 treatment facilities;
  - Number of households without access to aid (food distribution and water).

Adjustable Inputs

Variable	Effect	Range
Block-size shelters	Number of shelters in one block, divided by roads	60 or 120
Shelter plot size	Scale of the model	12.5 / 25 / 50 / 100 m2 per shelter
Facility conditions	Determines whether number of facilities is limited or good	*Limited* or *Good*
Factor asymptomatic	Factor to increase the share of people that are asymptomatic	1 / 2 / 3
Queue distance	Distance maintained by people in queues	0.5 / 1.0 / 1.5 m
Movement restrictions	Policy option determined movement for (infected) people)	Free / quarantine / isolation / no-elderly
Compliance	Chance that a person will comply to movement restrictions	0 - 100%
Food delivery day	No. days until first food distribution happens (repeats every 28 days)	1 - 27
Use of masks - and effect	Policy option to require mask-usage and the effectiveness of masks	Yes or no 0 - 100%

Model Cards

Modelling COVID-19 in Refugee Settlements

TU Delft

Model Cards

- Input parameters
  - Settlement layout;
  - Demographics & Households;
  - Facilities in settlement;
- Model logic and assumption
  - Basic daily routines of refugees;
  - Exposure to COVID-19 (infection);
- Intervention assumptions
  - Policy options;
  - Treatment facilities.

Input Parameters

Model Cards

- Settlement layout
- Demographics & Households
- Facilities in settlement

TU Delft

Settlement layout

- A generic camp layout has been developed on the basis of the key features from different refugee camps*:

General assumption	Amount	Metric
No. shelters in camp	240	shelters
Family size	5	people
Shelter plot size	12.5 / 25 / 50 / 100	m2
No. shelters in blocks	60 / 120	shelters

*Camps considered: Kakuma, Moria, Za'atari, Bidi Bidi and Cox's Bazar

- Several features such a shelter plots size and size of shelter blocks can be adjusted at the setup of the model.

Demographics & Households

- The model is set up with 1200 inhabitants in default, according to the following demographic distribution:

Demographic	Amount	Percentage of population
Elderly (60+)	96	8.0%
Adults	480	40.0%
Children (<18)	624	52.0 %

Note: No distinction has been made on the basis of gender.

- Each shelter represents a household of 5 people with different demographic compositions;
- Individuals are modeled separately when they are sick/recovered.

Facilities in settlement

- Different facilities are modelled within the refugee settlement:
  - Latrine blocks;
  - Water points;
  - Food distribution points;
  - Healthcare facilities;
- Facilities are located at two edges of the camp;
- Facilities have set opening times;
- The number of facilities is determined according to the number of inhabitants and the predetermined camp conditions.

TU Delft

Model Logic & Assumptions

Model Cards

- Daily routines of refugees
- Exposure to COVID-19 (infection and disease progression)

TU Delft

Daily routines of refugees

- Inhabitants perform the following key activities throughout the day (from 6AM to 11:30PM), which are initiated at random moments:

Activity	When	Who
Using latrines	7 x per day	random individuals from household
Fetching water	1 x per day	one individual per household
Obtain food from distribution point	1 x per 4 weeks	one individual per household
Consult health care facilities	when sick	every individual

- Food and water are preferably obtained by a household member who believes to be not infected (i.e. perceived infection);
- Food cannot be obtained by children.

Basic daily routines

- When initiating an activity people arrive at a facility instantly

  [Note: travel within the refugee settlement has not been taken into consideration, as the risk of COVID-19 transmission thereof has been considered minimal];
- People queue at a facility when necessary, maintaining a predefined distance from one another within the queue

  [Note: distance within queues can be adjusted before the set-up of the model];
- After an activity, a person returns to its shelter instantly;
- The primary focus lies on transmission of the virus within the camp, travelling in- and out of the camp can be mimicked by creating random new infections.

TU Delft

COVID-19 infection

- Initially, one person is at random exposed to the COVID-19;
- Transmission occurs when people are in close distance of a person infected with COVID-19

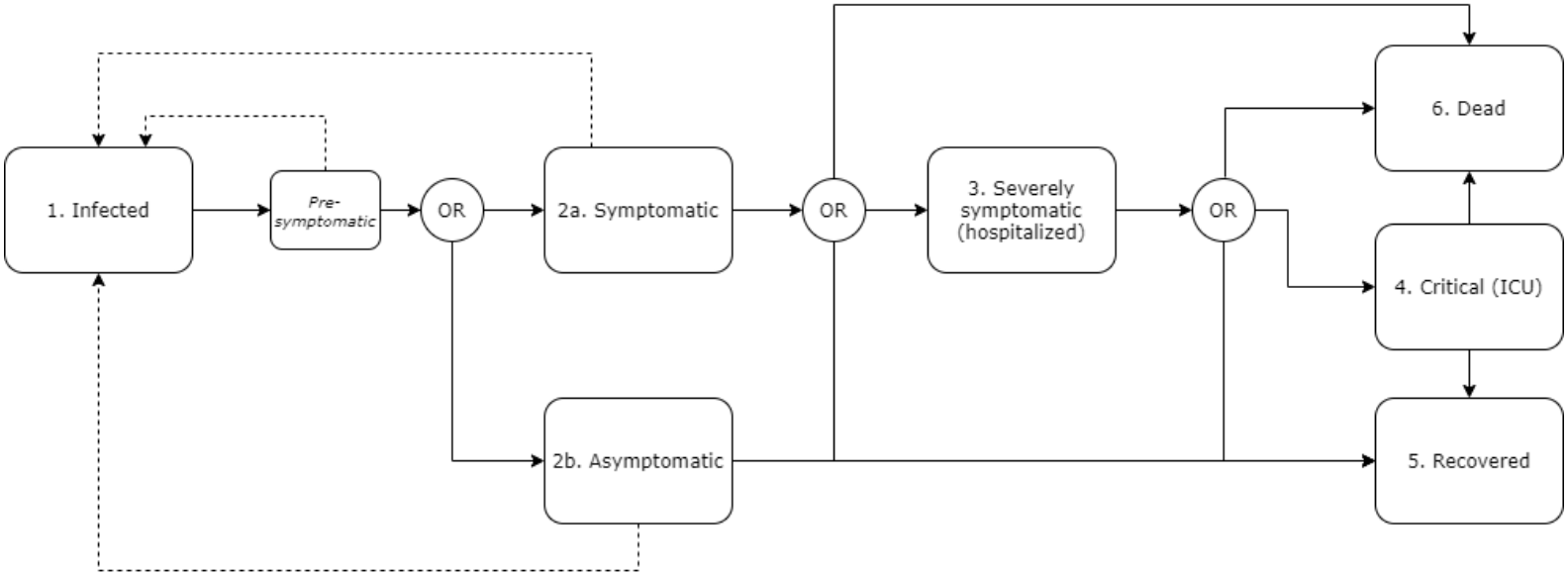
  (probability is determined on the basis of proximity, duration and age);
- People become infectious after an incubation period

  (this is independent of their health status).

COVID-19 infection

- Agents have one of the following disease stages:
  - Healthy
  - Sick
    - presymptomatic
    - asymptomatic
    - symptomatic
    - severely symptomatic
    - critical
  - Recovered
  - Dead
- Infection perception can differ from actual infection status and is either healthy, infected or immune. Agents can suspect an infection when having symptomatic household members.

COVID-19 disease stages



COVID-19 disease progression

- Once a person has been infected, its disease status changes over time;
- The disease progression across the disease stages is different for each age group;
- The time between different disease stages is determined using a random distribution;
- The next disease stage gets determined per person upon transition to a new state.

Intervention Assumptions

Model Cards

- Policy options
- COVID-19 treatment facilities

TU Delft

Policy options

- Different policy options can be implemented at the start of the simulation in order to prevent or mitigate the spread of COVID-19 transmission within the modelled environment:
  - social distancing in queues;
  - movement restrictions;
  - use of face masks;
  - separate facilities for COVID-19 infectees (future work);
- Compliance rates determine what percentage of people complies to policies.

[Note: compliance rates can be adjusted before the set-up of the model]

TU Delft

Policy options

- Social distancing in queues
  - People maintain 0.5 / 1.0 / 1.5 distance in queues (policy option)
  - 100% compliance to this rule
- Mask usage
  - Reduces chance of virus transmission with a predefined percentage
- Movement restrictions
  - Free movement in the camp (no restrictions)
  - Quarantine (person stays home when perceived infection)
  - Isolation (entire household stays home when 1 person is perceived infection)
  - Elderly stay at home (except for visiting COVID-19 treatment facilities)
- Movement restrictions are adhered on the basis of perception as to whether a person (within the household) has been infected and compliance rates.

COVID-19 treatment facilities

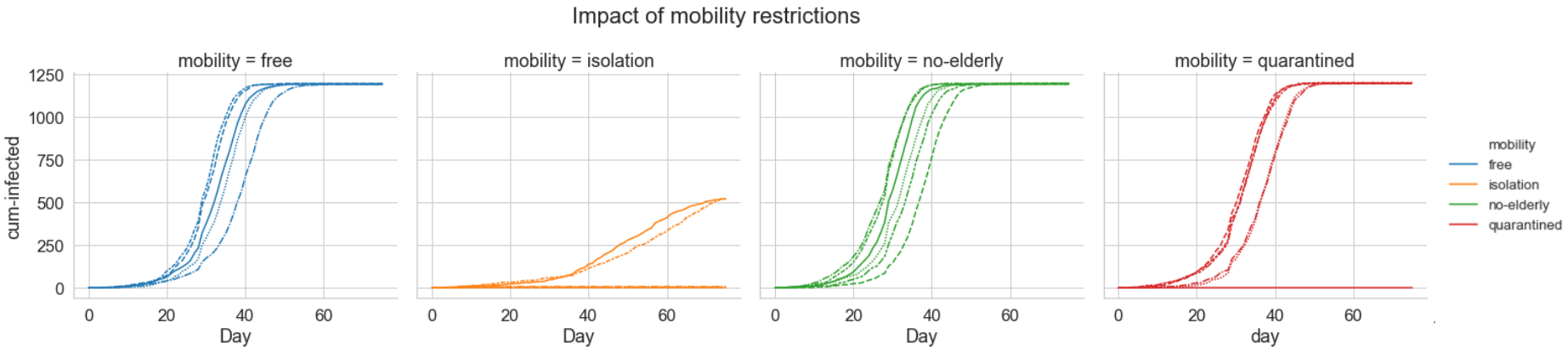
- Treatment facilities can be created at setup or during a simulation run and have a fixed capacity:
  - Treatment capacity for severely symptomatic patients, i.e. 100 beds;
  - Intensive care capacity (IC) for critically symptomatic patients, i.e. 8 IC units;
- Patients will always go to a COVID-19 facility when they become severely or critically ill (even under certain movement restrictions);
- If all ICU capacity is occupied, critical patients obtain a regular hospital bed.

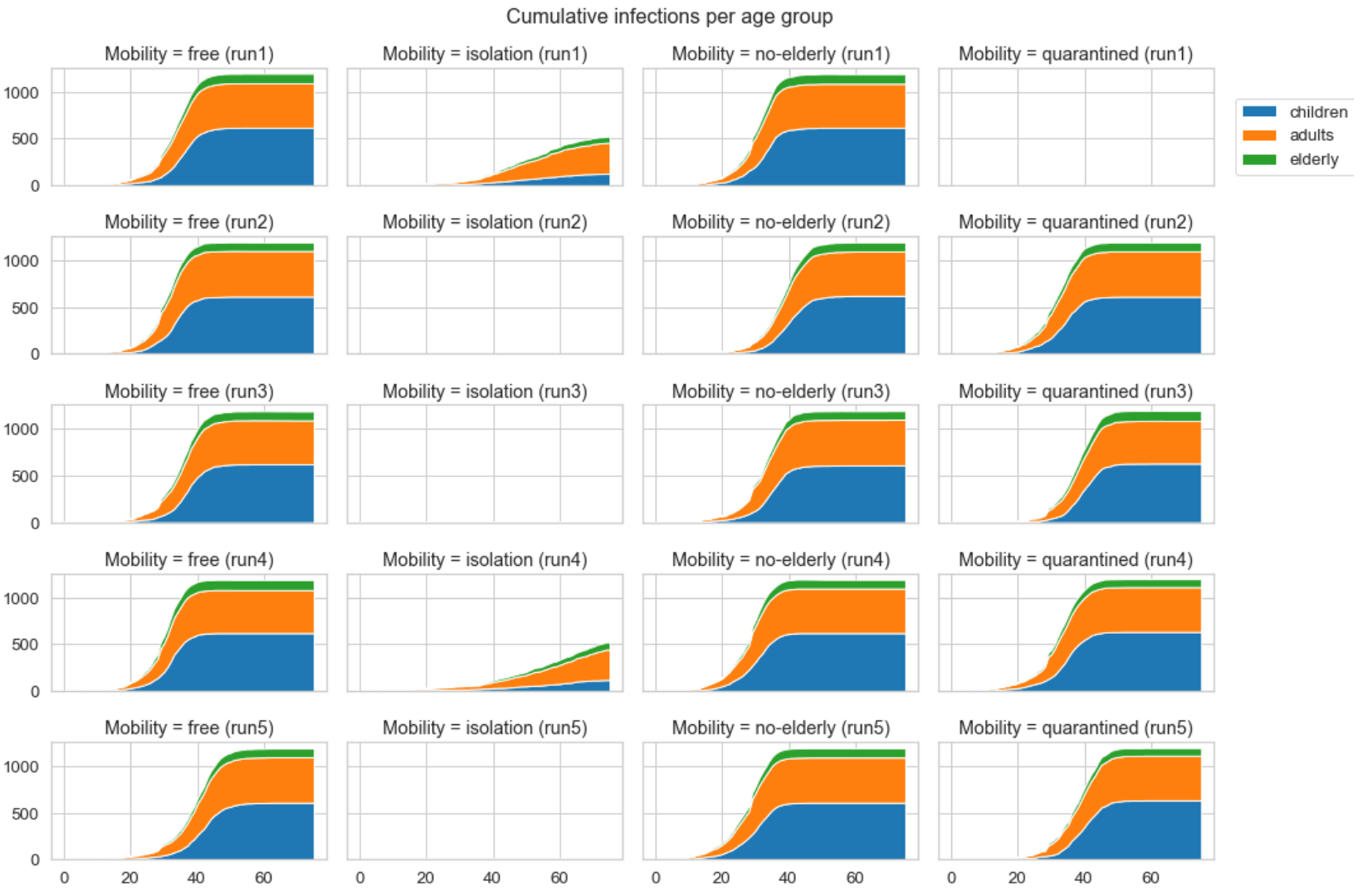
TU Delft

Results

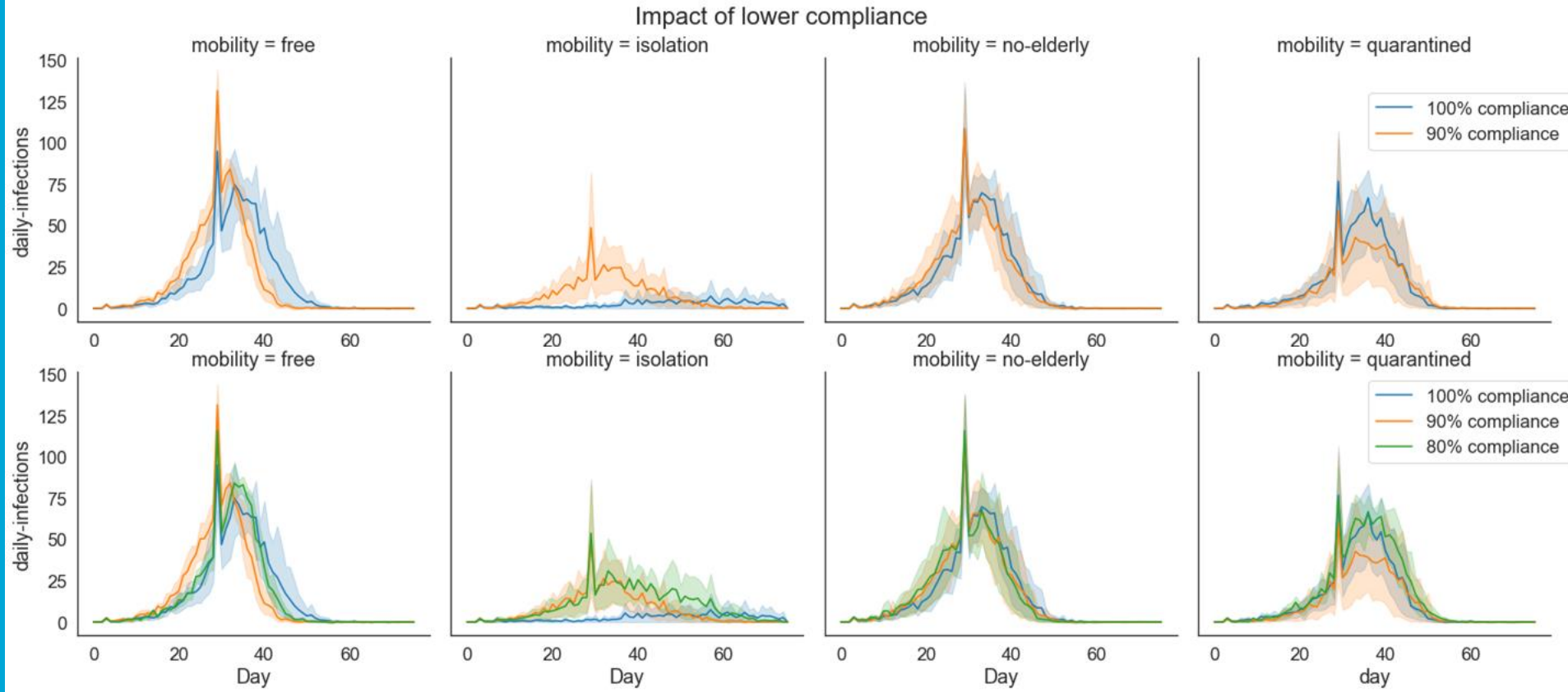
Modelling COVID-19 in Refugee Settlements

Effect of mobility restrictions:

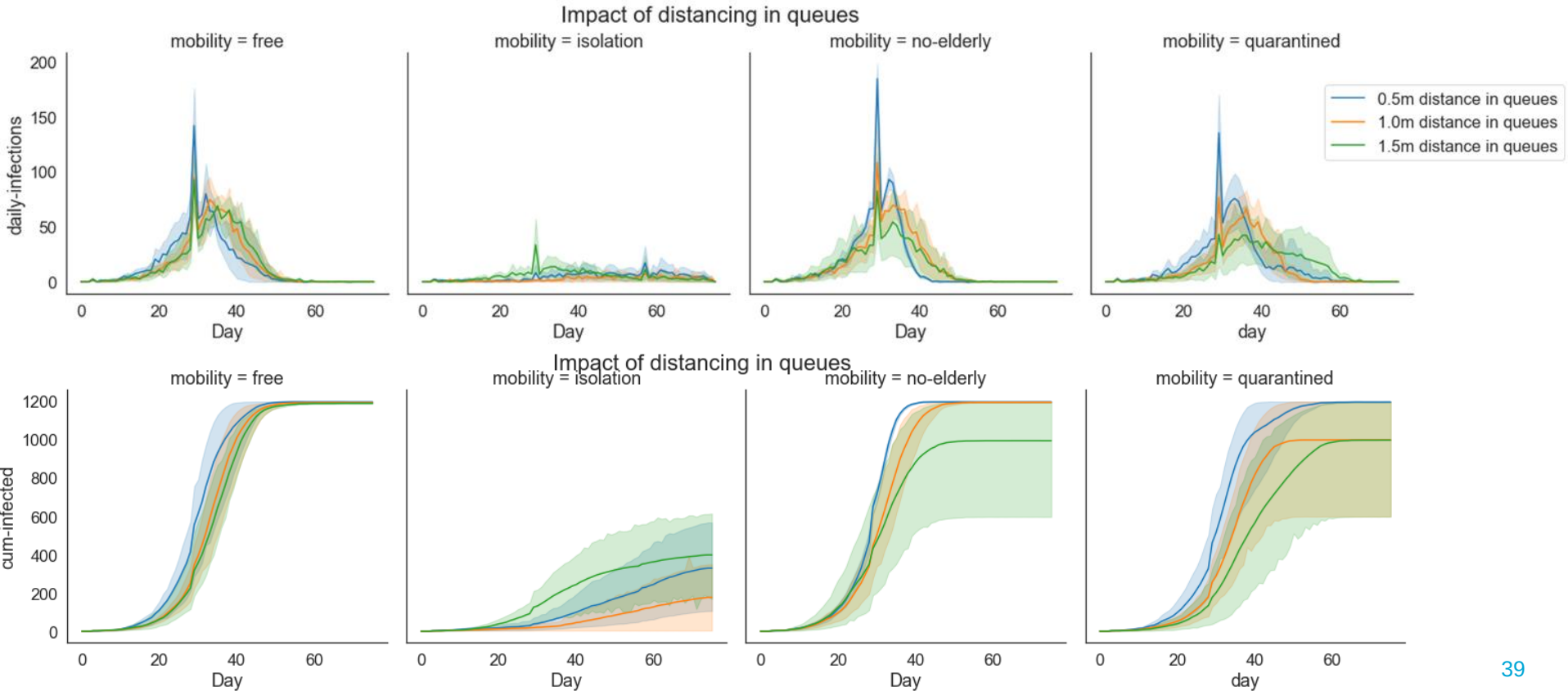



Cumulative infections per age group
Mobility = free (run1)
Mobility = isolation (run1)
Mobility = no-elderly (run1)
Mobility = quarantined (run1)
Mobility = free (run2)
Mobility = isolation (run2)
Mobility = no-elderly (run2)
Mobility = quarantined (run2)
Mobility = free (run3)
Mobility = isolation (run3)
Mobility = no-elderly (run3)
Mobility = quarantined (run3)
Mobility = free (run4)
Mobility = isolation (run4)
Mobility = no-elderly (run4)
Mobility = quarantined (run4)
Mobility = free (run5)
Mobility = isolation (run5)
Mobility = no-elderly (run5)
Mobility = quarantined (run5)
0
500
1000
0
20
40
60
children
adults
elderly

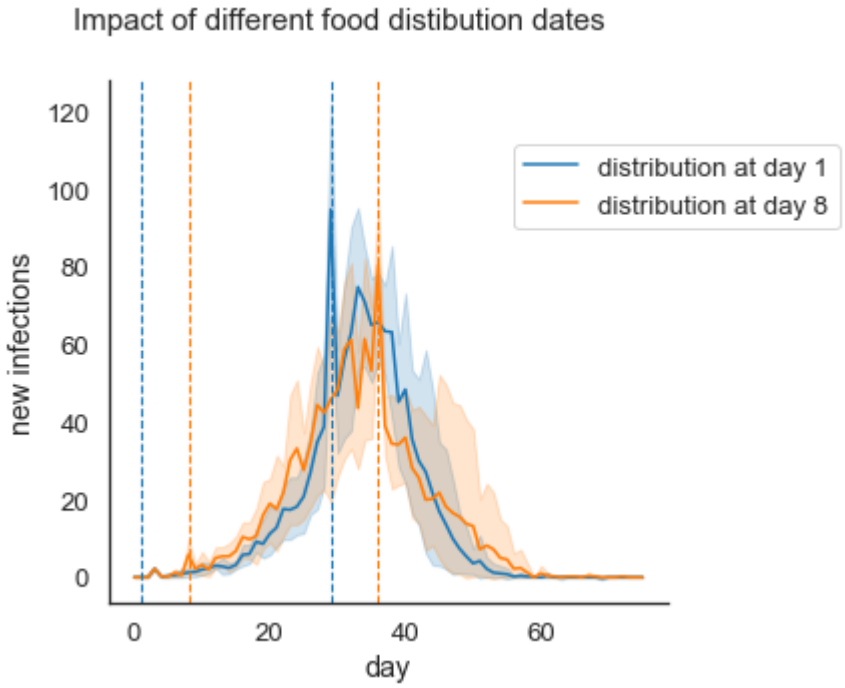
Effect of lower compliance



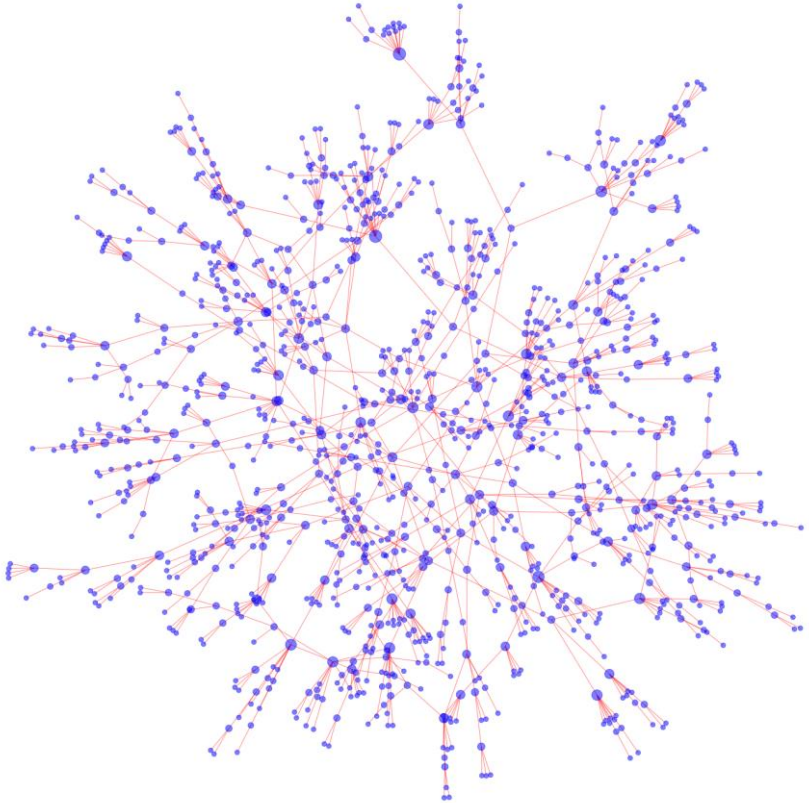
Effect of larger queue-distance



Impact of shifting food distribution day



Visualizing the infection network



Team & contact

Dr. Tina Comes
Principal Investigator, TU Delft
t.comes@tudelft.nl

Mariken Gaanderse
Manager ResilienceLab, TU Delft
m.q.gaanderse-1@tudelft.nl

Meyke Nering Bögel
Researcher, TU Delft
meyke.nb@gmail.com

Thomas Baar
Strategic Advisor, UNU-MERIT
baar@merit.unu.edu

Links

- Github repo: https://github.com/MeykeNB/Covid-19-in-refugee-camps

TU Delft