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1 Introduction

Are some urban environments more resistant than others to cope with a pandemic such as the one caused by COVID-19? This question is at the heart of many debates because this pandemic reminds us how vulnerable urban populations can be. It invites us to explore how policies could take advantage of the knowledge of local epidemic dynamics in given morpho-functional contexts to become more place-specific.

The problem is that although an impressive amount of data is now available regarding the impact of the pandemic in different geographical contexts, it is almost impossible to determine the relative importance of the spatial context in comparison to, for instance, social, cultural, epidemiological or political factors. A possible approach to disentangle those determinants is to use realistic simulation models in which the impact of different morpho-functional organizations on the effectiveness of public health policies would be evaluated.

Many models have been produced in recent months to respond to the emergency. While many of these models do not allow space to be taken into account, others, and in particular agent-based models [1], allow it and thus enable realistic morpho-functional organizations to be considered. This is the path followed by the COMOKIT[7] (COVID-19 Modelling Kit) framework [3]: COMOKIT combines sub-models of person-to-person and environmental transmission, a sub-

[7] https://comokit.org

model of individual epidemiological status evolution, an agenda-based one-hour time step sub-model of human mobility, and a policy intervention sub-model.

We propose in this paper to use COMOKIT to study the impact of the morpho-functional organization of a city on the containment policies that can be put in place.

2 COMOKIT in a nutshell

COMOKIT has initially been developed to respond to the Vietnamese government's need for tools capable of assisting in decision-making on intervention policy choices (containment, mandatory mask wearing, etc.) at the scale of a small town (about 10,000 inhabitants). However, it has been designed to be modular, extensible and able to be deployed in different case studies, with different available input data.

The core entities of the model are the *Individual* agents: they represent interconnected (relatives, friends, colleagues, etc.) individual inhabitants of the commune with their individual characteristics (age, gender, employment status) and their epidemiological status. They perform daily activities depending on their personal agenda. This agenda is a generated set of *Activity* that can be shared by several individuals (*e.g.* going to a restaurant with some friends), depending on the age and family status of the Individual agent. *Building* agents are the atomic spatial entities where the *Individual* agents can perform an *Activity*. Two special *Building* kinds have been defined as they have an important role in the simulation: *outside*, that represents everything outside the studied area, and *Hospital*, where sick individual agents with critical symptoms can be contained and healed.

A simulation step is set to represent 1 hour and starts by the agent to agent transmission: contagious *Individual* agents infect other susceptible agents in the same building based on a successful contact conditional probability. Then all *Individual* agents update their epidemic status, e.g. going from susceptible to infected. Next, they execute their daily activities depending on authority allowances. Finally, the Authority agent checks its current Policy and apply it, e.g. to test inhabitants.

3 COMOKIT Azur

To study the impact of the morpho-functional organization of cities on the spread of COVID-19, we focus on the case study of the urban area of Nice (France) which has been hit particularly hard by the pandemic and is considering the use of place-specific policies. We thus applied the COMOKIT model on 3 subareas with very different organization [2]:

- *Nice city center*: this is a compact pedestrian-friendly 19th century city, characterized by high urban density in the form of adjoining apartment buildings, finely meshed urban grid, many leisure facilities and small stores.In addition,

this subarea is used by a large population living in other districts of Nice who come here to do activities (work, shopping, leisure activities, etc.).
- *Nice suburban residential area*: this area lies outside of the city of Nice proper and is characterized by low population density in single-family homes with gardens, and an equally low level of services. Functional specialisation is the hallmark of this area, which also includes some concentrations of car-based commercial buildings. The overwhelming majority of residents work outside of this subarea. Few outsiders come to the subarea to carry out activities.
- *Nice modernist peripheral area*: this subarea is in an intermediate situation: this subarea is densively populated and mainly composed of collective housing, with a low level of service and a majority of inhabitants working outside of the area.

These different morpho-functional organizations beg the question of the favored patterns of encounter in the context of the COVID pandemic and of the possible impact of local containment policies.

We initialized the model using French high-quality data sources: the INSEE (French national institute of Statistics) and IGN (French National Institute of Geography) in addition to OSM data. Simulations were executed from January 24 to October 20, 2020, taking into account the epidemiological context of this period. On each area, we tested three scenarios: the absence of an intervention policy (basic scenario), a realistic policy inspired by government action in France and a hypothetical policy of closing urban areas. Each of the three scenarios follows the temporal development of the measures taken in France during the 1st containment between March 17 and May 11, 2020.

50 replications for each area and each policy were carried out to take into account the stochasticity of the model.

First results. Among other contrasting responses to the French lockdown scenario the simulations carried out allow to highlight a cleavage: on the first hand, suburb area has being relatively protected against the outbreak, while on the other hand, the two other areas have been hit by a curve up after the release of the intervention, even sharper for the intermediate area. This might be explained by the relative openness of the last two areas, where a half and almost one third of the population of agents come from outside of the studied area. It clearly supports the observation that lockdown in itself is not able to stop the outbreak if it is not followed by targeted interventions to fight again the re-introduction of new cases.

Another aspect to analyse is the differences regarding the epidemic rebound: it is sharp in the intermediate area, contained in the city center, and smooth in the last. This may be explained by the structure of activities and functional aspects of the urban area: in the city center there are a lot of small workplaces and retails that lead to a relative low and consistent number of daylong contacts and a large number of small contacts with interchanging agents; in the suburb there is very few contacts related to activities such as shopping and working but many prolonged contact with the same agents again and again, like relatives

and friends; finally the intermediate area has a lot of large building that host workplaces or mall, leading to a large number of prolonged daylong contact between agent from within and outside the area. This contrasting responses should be considered when deploying a unified intervention policy and might be more effective if considered in conjunction with the specificity of the morpho-functional aspects of urban areas.

4 Conclusion

In this proposal we briefly introduce the COMOKIT framework that makes it possible to study the outcome of intervention policy over the course of a SARS-CoV-2 outbreak at the scale of a city. We apply the model on the city of Nice in the south of France and explore how different areas of the urban zone respond to interventions. In particular we demonstrate how important is the openness to outside areas to foresee lockdown style intervention efficiency and how provided activities and facilities in an area can impact the course of the outbreak after the release of the intervention.

While COMOKIT used in several context, we still plan to improve its ability to represent the new challenges to support mitigation strategies to fight against the pandemic. More precisely we want to make it possible to explore in depth spatial aspect of NonPharmaceutical Interventions (NPI), for example we want to add new feature in the framework to easily implement and test policies entailed by proposition related to the "NoCovid" strategy and the identification of Green zones with territorial based planing of the interventions.

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