Data-Driven Healthcare Planning: Simulating Emergency Departments Dynamics with an Agent-Based Model

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The optimization of healthcare systems is of paramount importance for the enhancement of patient outcomes, the improvement of resource allocation and the reduction of operational costs. Effective optimization leads to a reduction in waiting times, an increase in patient satisfaction and a more efficient utilization of medical resources. This, in turn, supports the sustainability and resilience of healthcare infrastructures, particularly in the face of growing demand and limited resources.

In the context of healthcare system optimization, we present an agent-based model (ABM) for simulating the emergency department (ED) territorial system of the ASST Sette Laghi. The objective of this model is to support policy-making in strategic decision-making.

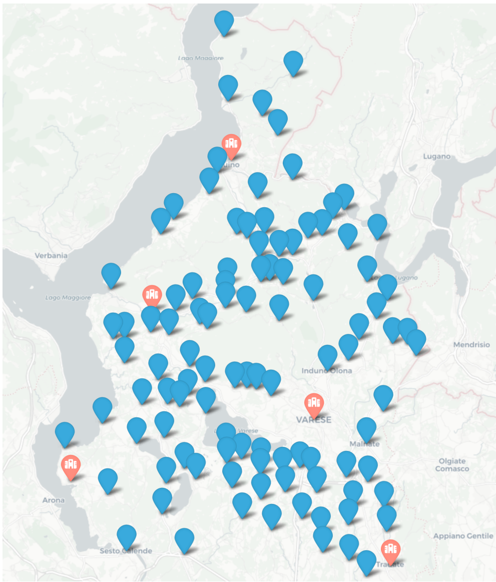


Figure 1, territory where the data were collected

This model employs real-world data to generate a realistic distribution of patients in terms of spatial distribution, age, pathology, and severity. The dataset comprises over 350,000 patient records collected over a two-year period (2019-mid 2022, with a break from 2020 and mid-2021 due to the Covid-19 pandemic). It encompasses six different structures and includes critical variables such as the number of doctors, patient arrivals at each facility, and waiting times.

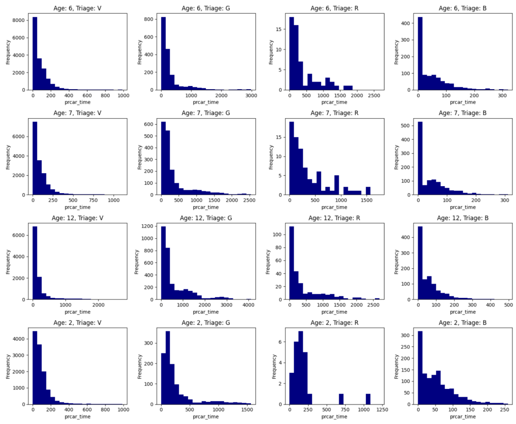


Figure 2, distributions of treatment time for different severity and age range of patients, for a specific pathology and a subsample of age ranges

The ABM was thus designed to replicate the existing conditions (the as-is scenario) of the ASST Sette Laghi ED system during the period of data collection. This model can accurately generate patients considering a range of demographic factors, including age, sex, and residency, as well as medical factors such as the type and severity of the condition. It can also consider the intersection of these elements and the conditional probabilities.

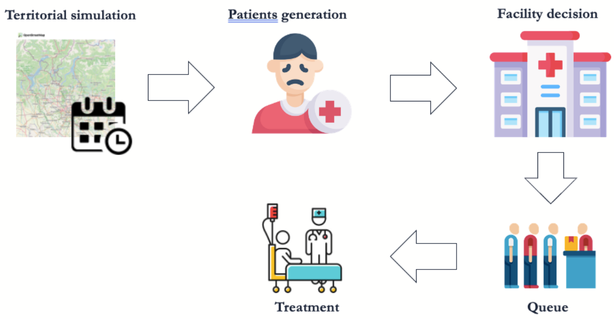
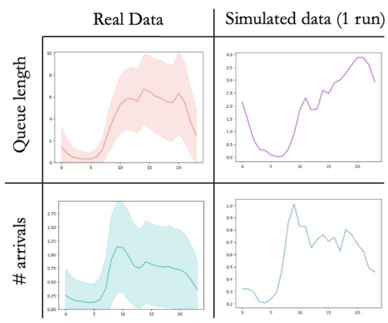


Figure 3, patient flow during a simulation

Firstly, the model was calibrated and tested against real-world data output in order to validate its behaviour. Subsequently, the ABM was utilised to perform what-if analyses in collaboration with local healthcare policymakers. These analyses aimed to explore the impacts of different strategic interventions, specifically focusing on the optimal location and size of a new hospital within the province, which was due in the Italian track of the Next Generation EU. By simulating a range of scenarios, the model provided insights into potential improvements in patient wait times, resource utilisation, and overall system efficiency.



The findings of the simulations indicate that the strategic placement and sizing of new healthcare facilities can significantly alter the performance of the ED system. Enhancements to the system can be achieved through any modification, although the system is not yet at saturation. Therefore, the construction of a new hospital, optimally located based on patient distribution patterns and current facility capacities, could reduce waiting times and improve access to care.