

EQUiD– Digital approaches to structural inequalities in infectious disease response

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Context and rationale

Infectious disease crises expose and amplify structural health inequalities. Beyond biological exposure to pathogens, the capacity to reduce mobility, access healthcare, comply with preventive measures, and benefit from public health interventions is deeply shaped by socio-economic conditions. Epidemics therefore reveal not only patterns of transmission, but also territorial and social disparities that affect access to care, prevention, and protection among vulnerable populations^{1–3}. Addressing these inequalities is central to improving equity in global health.

EQUiD adopts an integrated digital and bio–social perspective on infectious disease response. Leveraging large-scale digital mobility data, the project develops innovative methods to quantify collective adaptive responses and examine how digital indicators can reveal inequality-sensitive epidemic dynamics.

Positioned within the **Santé & Environnement** axis (infectious diseases), EQUiD contributes to the **Humanités biomédicales** axis through the analysis of structural health inequalities and to the **Santé digitale & technologies** axis through innovative digital epidemiology methods based on large-scale mobility data. By integrating social determinants of health with digital analytics, the project supports equity-oriented prevention and decision-making.

The 2014–2015 Ebola epidemic in Guinea provides a critical empirical setting to investigate these mechanisms in a low-resource context where structural inequalities may strongly influence epidemic dynamics. Digital mobility data have proven valuable to capture population movements during epidemics, yet their potential to inform inequality-aware public health strategies remains underexplored. By developing transferable analytical frameworks, EQUiD seeks to generate knowledge applicable to future infectious disease crises in diverse global settings.

Objectives

EQUiD aims to develop digital approaches to quantify how structural inequalities shape infectious disease response and to assess their implications for equitable prevention and access to care. The project pursues two interrelated objectives:

Objective 1: Characterize inequality-dependent adaptive capacity. Quantify how mobility and communication patterns varied across socio-economic contexts during the Ebola epidemic, identifying differential adaptive capacity linked to poverty, segregation, and resource access.

Objective 2: Measure network reorganization and socio-economic segregation. Reconstruct time-varying mobility and communication networks to assess whether crisis dynamics intensified segregation or altered connectivity patterns relevant to information diffusion, prevention, and healthcare access.

Together, these objectives integrate digital health innovation with the analysis of social determinants of health to inform more equitable infectious disease response.

Description of work

The project combines statistical and mathematical modeling with digital data analysis and sociological analysis of socio-economic stratification and network segregation to investigate how structural inequalities shape mobility and communication patterns during health crises. By developing scalable digital health analytics, the project aims to generate inequality-sensitive indicators that can inform prevention strategies and public health decision-making.

Data. We will use anonymized Call Detail Records (CDRs) from Orange, capturing billions of interactions from approximately 9 million users in Guinea during the 2014–2015 Ebola outbreak. Each record includes metadata on calls and SMS exchanges, such as anonymized IDs, timestamps, duration, and cellular tower locations. These data will be combined with spatial socio-economic

indicators from the Guinean Government⁵, including poverty, education, household composition, and healthcare infrastructure, and high-resolution maps of the Relative Wealth Index⁶. We will also use daily reported Ebola cases and deaths from the Humanitarian Data Exchange platform⁷ to characterize the different phases of the outbreak.

Ethics Statement. The mobile phone data, provided through a partnership with Orange, will be fully anonymized and processed within secure Orange environments, ensuring strict adherence to privacy and confidentiality standards and GDPR compliance. All other datasets used in the project are aggregated, anonymized, and sourced from publicly available resources.

Task 1: Adaptive behavioral indicators. Using anonymized Orange CDR data, we will reconstruct mobility and communication behaviors across socio-economic groups during the Ebola outbreak and quantify indicators such as travel distance, trip frequency, mobility reduction, call activity, and contact diversity. The association between socio-economic status and mobility change will be assessed using spatial statistical models³. This task will determine whether disadvantaged groups faced greater constraints in adapting mobility and social connectivity, with implications for equitable prevention and healthcare access.

Task 2: Network and segregation analysis. This task will examine how mobility and communication networks reorganized along socio-economic lines during the Ebola outbreak. Time-varying networks will be constructed from CDR data, with nodes representing individuals and edges capturing communication or co-location. Socio-economic assortativity indices will quantify network segregation, and longitudinal analysis will track its evolution over the course of the epidemic. The analysis will assess whether interventions intensified socio-economic segregation or whether certain connectivity patterns facilitated bridging across divides.

Interdisciplinary framework and partnerships. EQUID is led by Vittoria Colizza and integrates complementary expertise across epidemiology, sociology, digital health, and public health systems:

- **Infectious disease modeling (*Santé & Environnement* axis):** Led by Colizza at INSERM and Sorbonne University Modeling Outbreaks Center (SUMOC), supervisor of the PhD thesis.
- **Social determinants and inequalities (*Humanités biomédicales* axis):** Co-supervision by Michele Tizzoni, contributing expertise in digital sociology and socio-economic analysis
- **Territorial digital analytics (*Santé digitale & technologies* axis):** Partnership with Orange, for secure analysis of large-scale mobility data and development of digital health indicators.
- **Public health system:** Collaboration with Prof. Abdoulaye Touré, Director of the National Institute of Public Health in Guinea to ensure institutional anchoring and policy relevance.

This interdisciplinary structure ensures articulation between biological mechanisms, social determinants of health, and digital innovation, fully aligned with the ASU-GHI framework.

Impact and contribution to global health. EQUID generates actionable evidence on structural health inequalities in infectious disease response. The project will co-develop policy briefs with Guinean public health institutions and produce inequality-sensitive digital indicators to inform prevention and preparedness strategies. By integrating digital innovation with the analysis of social determinants of health, EQUID strengthens ASU-GHI's positioning in global health equity and digital epidemiology. The methodological framework developed in EQUID is transferable to other infectious disease contexts, reinforcing ASU-GHI's capacity to address global health inequalities.

References

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