Challenges and Strategies for Information Systems in the Decision-Making Process to Face the COVID-19 Pandemic: The São Paulo Case

Alessandro S. Santos[1(✉)], Igor C. Teixeira[1], Rodrigo Neves[1], Icaro Gonçales[1], Angelina Inacio[1], Eduardo T. Ueda[1], Eduardo F. Z. Santana[2], Higor A. de Souza[2], and Fabio Kon[2]

[1] Institute for Technological Research – IPT – São Paulo, São Paulo, Brazil
{alesan,igort,rodrigoneves,icarogoncales,angelinasi,eduardoueda}@ipt.br
[2] Institute of Mathematics and Statistics – University of São Paulo, São Paulo, Brazil
{efzambom,hamario,kon}@ime.usp.br

Abstract. The State of São Paulo was the epicenter of COVID-19 in Brazil, with a high impact on society, causing many deaths and significant losses to the economy. A milestone in confronting the pandemic was creating an Intelligent Monitoring System, whose mission was to consolidate and integrate data to support the state government in its strategic decisions. Overcoming the challenges of integration, anonymity, and privacy was essential to validate and make governmental actions legal and ethical. We present the technical aspects, the information integration and good practices in disseminating strategic data on mobility, health, and economy to support strategic decision making.

1 Introduction

The global risk scenario caused by the COVID-19 pandemic revealed the weakness of the health system in several countries, the need for epidemic management, monitoring population data, and humanitarian support actions. Brazil does not have a recent history of a such a large biological natural disaster, and the COVID-19 pandemic presented itself as a huge challenge that involved several global challenges for public health, political, economic, and legal issues. Besides, due to the current political situation in Brazil, actions between municipalities, states, and the national federation did not have a harmonious integration.

The COVID-19 pandemic revealed operational vulnerabilities and the need to implement public policies related to information and communication technologies. Particularly, the use of data on mobility, health, and the economy, considering privacy issues, is essential for offering strategic information for evidence-based decision-making and efficient pandemic management.

A legal discussion about the privacy issues in pandemic scenarios in Brazil is still ongoing. There is no consensus on points of collision between the right to

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privacy and fundamental rights to health and life (in their collective spheres), demanding from the public authorities the creation of weighting targets, appropriate and proportional to the well-being of all [15].

Regardless of the maturity of the legal aspects, the pandemic forced several countries to act quickly, creating mechanisms to minimize the pandemic effects, requiring the creation of guidelines and technical structures to support decisions. The State of São Paulo was the epicenter of the pandemic in Brazil, with the highest population density, intensive international trade relations, and the largest COVID-19 situation room. This paper presents the strategies and technical concerns to overcome the challenges, as well as the integration and respect privacy rights without compromising the rights to health and life.

2 Actions, Privacy and Data Protection in the Pandemic

The control of population mobility is one of the challenges to face the pandemic [10], and different technologies can monitor the population movements to provide information on the results of public policies used to combat COVID-19; a restructured society and environment could increase the city resilience [7].

The ideal would be to have a monitoring approach that can be used in different phases of a pandemic, with legal and legislative support, to allow government officials to obtain, ethically and respecting citizen's privacy, more accurate and efficient information to combat the spread of a virus. This approach should be gradual, with clear criteria that define when to go one more level, to have more restrictive monitoring mechanisms, where collective rights have higher priority. At the same time, there must be a criterion for determining when these mechanisms should cease to operate and be undone without prejudice to citizen rights.

The telecommunication infrastructure has been the great technological partner to capture mobility patterns in several parts of the world, with good results for decision-making [14]. Using this framework, Fig. 1 shows an escalator approach analogy, where the rise or fall depends on the advance or setback of the

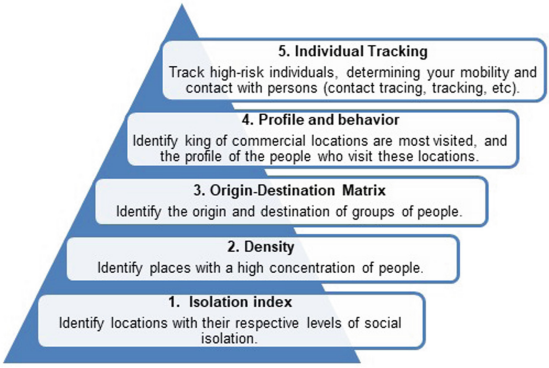

Fig. 1. Escalator approach for monitoring

spread of the virus [15]. This technological approach may be integrated into guidelines for privacy to avoid legal and individuals rights issues.

The European Commission guidelines for COVID-19 data management used local arrangements for fast implementation of information system to provide strategic data for decision-making to confront the crisis. The General Data Protection Regulation (GDPR) and Data Heath approach were the main support within this pandemic scenario.

Regarding COVID-19, the Data Protection Commission (DPC), the authority responsible for defending the fundamental right of individuals in the European Union (EU) to keep personal data protected, warned that it is necessary to focus in five main aspects: Lawfulness, Transparency, Confidentiality, Data Minimisation, and Accountability.

2.1 Scenarios and Perspective from Latin America

Table 1 presents an overview of actions in Latin American countries from a data perspective. We only considered countries that published consistent information that could support our analysis.

Three actions stood out. The first action concerns the location of individuals, used to measure the rates of social isolation. Another common action is the disclosure of the identities of patients infected with COVID-19 only with their consent, to respect privacy. The most prevalent action in all countries considered is the manipulation of data by healthcare professionals, mainly respecting the confidentiality of the information in the patients' medical records. An action that also deserves to be highlighted is data anonymization, since it contributes to guarantee the privacy of individuals when data are provided for public disclosure.

In Brazil, the national integration actions are not uniform in all states, and each state used a different approach. The State of São Paulo was the epicenter

Table 1. Mapping COVID-19 data in Latin America

Action	Locality				
	Argentina [1,2]	Chile [4,5]	Mxico [8,13]	Peru [16,17]	São Paulo [18]
Use of data location only with the user's permission	✘	✘			
GPS location, or cell towers,or Wi-Fi, or Bluetooth	✘	✘	✘	✘	✘
Data anonymization	✘		✘	✘	✘
Transparency of data usage with its owners	✘				✘
Incomplete data excluded from datasets	✘				✘
Drop the data when they are not more pertinent	✘			✘	✘
Disclosure of names of those infected with COVID-19 it must be with their permission	✘	✘	✘	✘	
History of diseases and user's medications		✘	✘	✘	
Health professionals can manipulate and transfer the data, but with confidentiality	✘	✘	✘	✘	✘

of COVID-19 in Brazil, with the largest number of cases and deaths due to its large population and density, as well as a larger connection to international sources of the disease. São Paulo established a series of legal instruments to confront COVID-19, the creation of a crisis management committee, technical councils, and the establishment of a quarantine starting on March 22, 2020. This crisis management committee put together a multidisciplinary team of nearly one hundred experts in Computer Science, Health, Geology, Transport Engineering, Economics, as well as Public Managers.

The Brazilian General Data Protection Law (LGPD) is the main guide for COVID-19 data protection in Brazil. The law was enacted on August 14, 2018, scheduled to come into force in 2020 [3]. Based on GDPR, the LGPD aims to protect personal data and applies to any person, natural or legal, under public or private law, who operates with this type of data.

The rights of data subjects are dealt with in several articles (art. 17 to 22) and include the right to information, access, anonymization, rectification, portability, elimination, information from public and private entities with which the controller made shared use of data and even revocation of consent.

3 The São Paulo Case

São Paulo created a situation room to face the pandemic including the Information Systems and Intelligent Monitoring (SIMI) tool that consolidates data collected from multiple state agencies. It is responsible for monitoring mobility data, health data, and economic impacts.

SIMI supports the formulation and evaluation of State actions to face the COVID-19 pandemic. The privacy issues were in a legal framework that determined that the system should not contain personal data, and it should consider the data anonymization.

The main modules monitor indicators such as mobility behavior (isolation index and traffic flows), healthcare data (hospital capacity, COVID-19 cases, deaths), and economic indicators.

3.1 Cellular Infrastructure as a Base for Identifying Mobility Behavior

Different parts of the world have been applying rules for social isolation, rapid detection tests, mandatory use of masks to prevent dissemination, as well as monitoring the movement of people using cell phones and other means [11,20]. These measures have shown good results in fighting the spread of the virus.

Cellular infrastructure was the base to monitor the mobility behavior in São Paulo. Therefore, the isolation index was the indicator to measure the result of public policy decisions regarding quarantine. The index presents the percentage of the population that remained inside their houses, creating an index by neighborhoods, cities, and states. The computation uses the cell phone connections in

the Cell Site to define the localization. Between 10 p.m. and 2 a.m., the connections define the "home Cell Site", thus, when a cell phone connects to another cell site (during all day), this action updates the isolation index.

The idea here is to apply the crowd sensing paradigm that takes advantage of the massive use of smart phones for collecting and reporting sensed geolocation data. But the successful deployment of these systems in real life has some challenges and the citizens' privacy is an important issue in order to increase the quality of the information in the system [19].

Mobile network operators collect data, applying anonymization procedures and grouping by regions, sending the information to the Big data environment of the Brazilian Association of Telecommunication Resources (ABR Telecom – Data Integrator). Then, the ABR sends the CSV files to the SIMI infrastructure for data visualization by the COVID-19 crisis committee (Fig. 2).

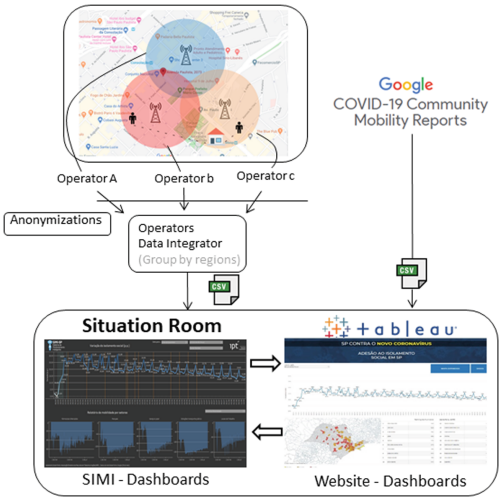

Fig. 2. Cellular infrastructure for monitoring isolation index

With regard to privacy, the Telecommunication Operators used the LGPD guidelines to build this ecosystem. Hence, it is not possible to obtain users' identification, address, mobile phone number, or individual locations.

For example, this approach and dataset were useful to the public actions and its results, evaluating the impacts in mobility pattern with trade closing; time restrictions for traffic flows; and anticipation of holidays.

3.2 Vehicular Mobility Monitoring

To understand the spread of COVID-19 across the São Paulo state, it is important to notice that the virus is carried by people while using the transport system. Thus, it is fundamental to map vehicle flows to capture the SARS-COV2 spreading patterns across the state to support the decision-making process.

To achieve that, we developed an information system integrating data from traffic counters via inductive-loops and speed cameras installed into highways, providing traffic flow of cars, trucks, and motorcycles.

These counters connect via fiber to traffic control centers from operators and supervisors companies (ARTESP, DER, WRITESYS), which send information using a REST API from a cloud broker, InterSCity [6], an integrated open-source platform containing all the major building blocks for the development of robust, integrated, sophisticated applications for smart cities [6]. Then, InterSCity stores data in a MongoDB database, and data visualisation tools (such as Tableau) are used to develop dashboards for the decision-making staff (Fig. 3).

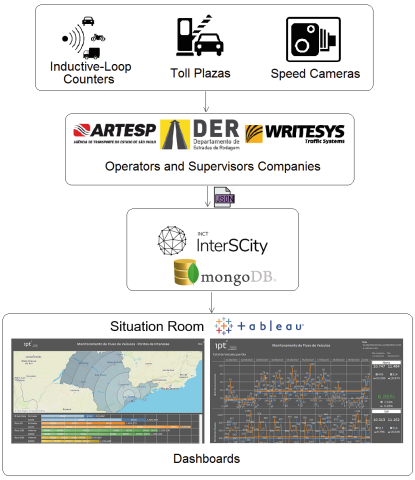

Fig. 3. Sensors data collection and visualization

This approach and dataset were useful to evaluate the impact of mobility on the spread of the virus outside the capital(epicentre) and its relationship with interstate highways; economic impacts based in mobility pattern [9]. Furthermore, the system did not compromise the license plate identification and individual origin-destination.

3.3 Health Data Monitoring

The data used to monitor the spread of COVID-19 in the São Paulo State were collected from integrated databases responsible for registering patients with severe acute respiratory illness (SARI). Figure 4 illustrates the process of integrating health systems by the State System for the Analysis of Statistical Data (SEADE Foudation) and the acquisition of international public data.

Due to the nature of the application, the bases contain many attributes of patient identification, making it necessary to apply anonymization techniques to build publicly accessible tools.

To extract relevant information, it is necessary to treat duplicate records, so each patient has only a single record. The suppression of the identifying attributes is responsible for generating the pseudo-anonymized data, where each line has a unique identifier that cannot be linked to the original patient.

The aggregation of data allowed the construction of geolocalized maps in which a town is the lowest level of detail. This way, it is possible to ensure that each record will belong to a large group, avoiding re-identification [12].

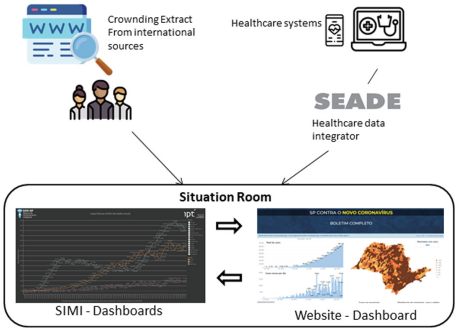

Fig. 4. Health data monitoring architecture

For example, this approach and dataset were useful to the public actions and its results, evaluating the spread of the virus into state, predicting resources allocation to supply hospitals operations, humanitarian support, logistic support for truck drivers transporting goods.

3.4 Fiscal Secrecy in Monitoring the Economic Rescue

The data used for analysis of the economic recovery refers to the amounts of Invoices and Electronic Tax Coupons issued daily and the total value of those documents, associated with the geographic location of the point of sale. These numbers are not enough to calculate the exact revenues because there is no treatment for returns, remittances, or transfers. However, they are a very good estimate of the point of sale activity.

Electronic Coupon data refer to the SAT-CFe (Electronic Tax Coupon Authenticator and Transmitter System) from retail trade and NFC-e (Electronic Consumer Invoice). The NFC-e is a digital document issued and stored electronically by a taxpayer accredited by the State Treasury Office, whose legal validity is guaranteed by the digital signature of the issuer and by the Authorization for Use, granted by the State Treasury Office, with the purpose to document sale operations in person or sale for delivery to the final consumer (individual or legal) in internal operation.

To handle this data, technical criteria of tax secrecy must be respected, making impossible to identify taxpayers and ensure privacy. Articles 198 and 199 of

The Brazilian Tax Code (CNT - National Tax Code) define tax secrecy. There is also the internal Resolution SF 20, which provides access to information protected by tax secrecy provided by computer systems of the State Treasury Office. In addition, article 325 of the Penal Code, states that revealing facts that should be secret can lead to the punishment of six months to two years of arrestment. Thus, all the rules must be carefully applied to ensure anonymization.

Weekly, the SIMI system receives a CSV file with data activity of the businesses associated with the São Paulo State Treasury Office, as depicted in Fig. 5. The file content follows all privacy rules described above. Using these data is a way to create the economic rescue dashboards in Tableau, showing the economic evolution of the State of São Paulo, compared to the year 2019.

This approach and dataset were useful to evaluate the impact of opening up the economy, define financial support to industry and the more affected sectors.

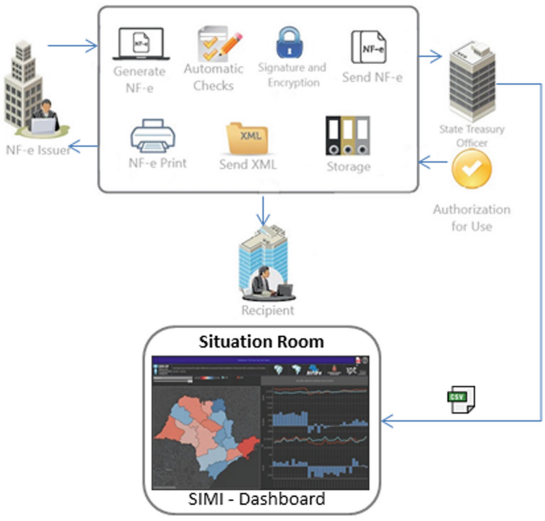

Fig. 5. Economical rescue monitoring

3.5 Escalator Approach in São Paulo

During the SIMI operation, several technologies provided new features to support the state government decision-making process. Thus, it was possible to associate Fig. 1 with actions undertaken in São Paulo, as shown in Table 2.

Table 2. Escalator approach in São Paulo

Escalator level	Modus operandi
Isolation Index and Density	The Cellular Operators use LGPD guidelines to offer the index using anonymous connections in Cell site, as well as the density maps
Origin-Destination Matrix	The Highway Operators use LGPD guidelines to offer the anonymous flows and tags from Automatic Vehicle identification to O-D Matrix
Profile and behavior	Google offers community mobility reports (https://www.google.com/covid19/mobility/) with csv files, which are used by SIMI dashboards to show relative mobility to 4 classes: retail and recreation; supermarket and pharmacy; parks; public transport stations; and workplaces. Besides, the monitoring of electronic invoice promotes an understanding of economic rescue, and in the case of retail could reflects the acquisition of goods and services in these locations
Individual tracking	São Paulo did not use this feature

4 Conclusions

This experience highlighted the importance of government information systems in offering an integrated view, to enable efficient monitoring of the results of public policies in facing the pandemic. It became evident the absence of mature privacy policies and jurisprudence on the use of data for pandemic periods. This caused friction and instability in the situation room work and multiple difficulties in implementing good practices already consolidated in other parts of the world.

Finally, it also demonstrated that the work of multidisciplinary teams and data integration were essential to aggregate and subsidize government officials in evidence-based decision-making to face the pandemic. This paper presents a new way of approaching local problems, based on the large technological body of work developed by network and data integration researchers in the past decades and explains how it has been applied in a real situation.

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