CITÉ-ID LIVING LAB

Gouvernance de la résilience urbaine

Urban resilience governance

Gobernanza de la resiliencia urbana

OBSERVATOIRE INTERNATIONAL SUR LES IMPACTS SOCIÉTAUX DE L'IA ET DU NUMÉRIQUE

October 25, 2021

The resilience of public health system to COVID-19 : the development of information systems by regional public health directorates in Quebec Executive summary

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Introduction

One of the main functions of public health is to monitor the health of the population through the collection, analysis and sharing of data to support decision-making. Controlling pandemics depends on the ability to detect and contain clusters of infection in order to interrupt community transmission. Data help guide interventions, based on an understanding of infection transmission at temporal, spatial and individual level (Budd et al., 2020). This includes identifying cases and contacts, as well as exposure and transmission environments.

In collaboration with OBVIA and Regional Public Health Directorates (RPHD) in Quebec, the Cité-ID Living-Lab of the École nationale d'administration publique (ENAP) was mandated to conduct research on the use and development of information systems and digital tools by Quebec public health during the COVID-19 pandemic. Semi-directed individual and group interviews were conducted with regional directors and epidemiological, surveillance and IT teams in six RPHDs. Our research examined the creation of a pandemic-resilient public health system as a socio-technical system built on the interaction between technologies and social governance institutions. It aimed to understand the complexity of the public health information system in Quebec and identify technological and organizational factors that limit or facilitate the development of system resilience, assessed by the ability to access, analyze, and share data.

Information Systems in public health: accelerating the digital transition in the context of the COVID-19 pandemic

While computerization of public health systems stand to improve disease surveillance and control capabilities, they tend to develop very slowly. They are at different stages of development in health institutions and rely on both paper and computerized processes, which hampers the integration of information systems data and their interoperability: the ability of different systems to communicate with each other (Haux 2006; AbouZhar and Boerma 2005; Gopal et al., 2019).

The COVID-19 pandemic accelerated the digital shift in public health information systems around the world, notably through the use of dashboards for real-time data visualization; the development of tools for symptom self-assessment and automatic public health notifications; and digital contact tracing applications (Budd et al. , 2020).

At the start of the pandemic, Quebec's public health information systems were ill prepared for a crisis of this magnitude. Significant problems related to integration and interoperability were revealed, based on computer tools that operated independently of one another. In fact, when the pandemic began, the health authorities' communication and information systems were still dependent on paper processes, manual data entry and the fax machine. As a result, health authorities were forced to quickly adapt and change their practices, developing digital tools to permit gradual but incomplete integration of data at national level, along with tools developed in-house by teams at regional level to better meet information needs.

Use and usefulness of digital technologies in public health

Public health management of the COVID-19 crisis highlighted the need for real-time data. The Ministry of Health and Social Services (MSSS) and the DRSPs used information systems and digital tools for decision-making on crisis management, using data on the number of cases and contacts; the rate of transmission on a territory (at-risk and outbreak settings); the number of people hospitalized and in intensive care, and hospital capacity (number of staff in quarantine, number of beds and ventilators).

Some integrated health and social services centres (CISSS) and integrated university health and social services centres (CIUSSS) developed dashboards to visualize data in real time. These enabled regional directors to make better decisions, instituting directives for isolating cases and contacts, setting up care units, supporting high-risk settings (CHSLDs, educational, childcare and work environments), and providing information to policy makers, the media and the public.

The implementation of the Akinox platform at the national level in April 2020 allowed for the production of a single daily report for all regions, which was useful in understanding the evolution of transmission in different regions, as well as reducing the workload of regional surveillance teams who were required to produce a daily report at the onset of the pandemic.

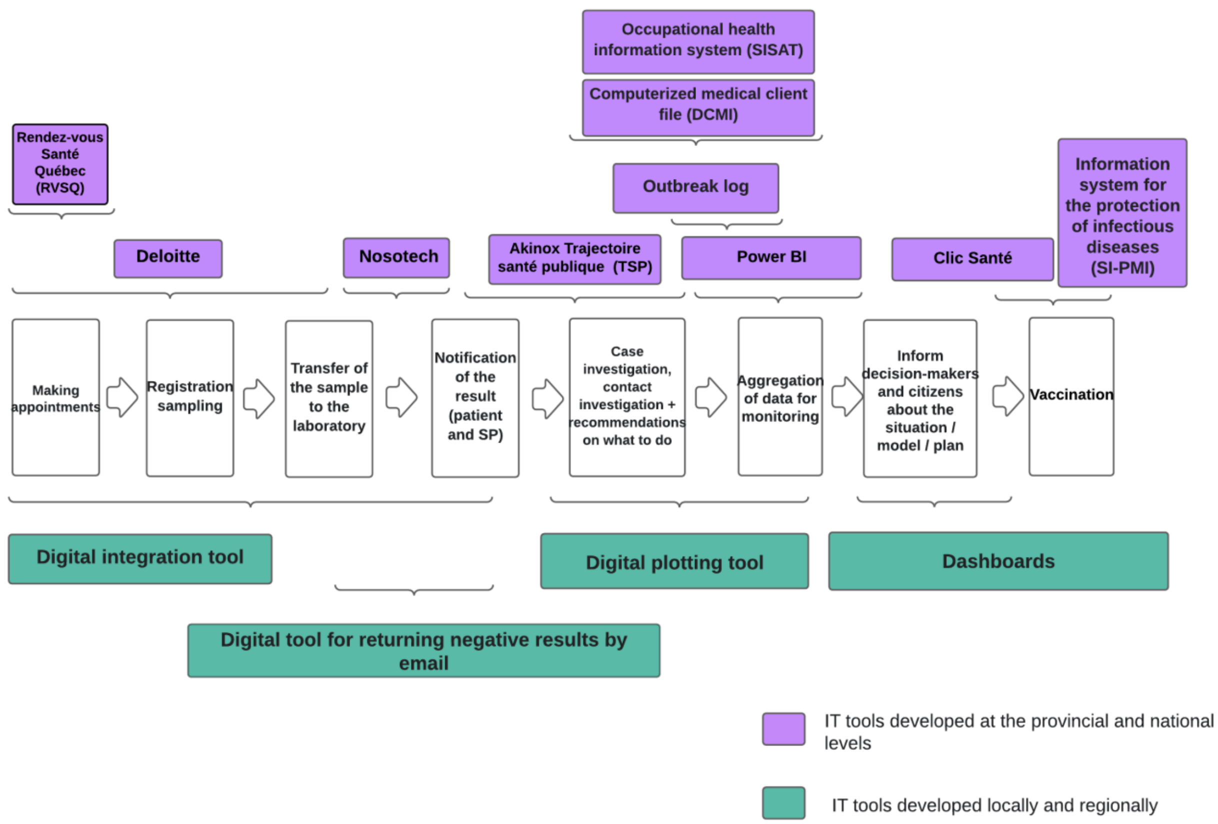
Development and use of digital tools in the context of the pandemic in Quebec

As illustrated in the diagram below, public health management of COVID-19 involved a number of steps: appointment-making, registration and sample collection; transfer of samples to the laboratory; sending results to patient and public health; case and contact investigation; aggregation of data for surveillance and reporting of results to policy makers and the public, and, most recently, vaccination.

Different digital tools to undertake these steps were developed and used by public health authorities at national, regional and local level. The top section of the diagram below shows computer tools developed at the provincial and national levels that are based on the steps in the COVID-19 management process. The diagram's bottom section focuses on tools developed at local and regional level. Fairly early in the crisis, during spring and summer 2020, regional and local authorities developed in-house IT and digital tools to improve processes for managing COVID-19. The gradual digital transformation itself was undertaken in phases. First, there was a reactive phase characterized by sending test results by fax or email, and manual analyses of social networks to understand outbreaks. Next came an organized effort using existing IT programs such as Excel and HP3000, as well as Intranet and Teams portals to supplement existing information, and SharePoint to manage telephone calls to positive cases and investigations of cases and contacts. These phases were followed by a digitization phase where digital tools were developed for call management, and dashboards were created for decision-makers using either in-house programs or Power BI to capture data from unconnected systems via manual inputs and semi-automatic processes. Finally, a truly connected phase began, enabling automatic and real-time data capture. As illustrated in the figure showing this last 'connected' phase, these are tools for integrating and automating COVID-19 screening (registration, sample collection, transfer for laboratory analysis, and laboratory transfer of results to public health), the communication of negative results via email, and tools for tracking and managing outbreaks in the workplace (such as TikiWiki), as well as dashboards to capture data from various computer systems in real time, enabling RPHDs to visualize real-time data based on a set of monitoring indicators.

The top section of Figure 1 shows the digital tools developed nationally and provincially according to the stages of the COVID-19 management process. Provincial authorities developed digital tools later on in the crisis during the fall and winter of 2020.

Figure 1: Classification of digital tools used by public health according to the pandemic management process



The main tools created by external developers at the provincial level include:

- The Rendezvous Santé Québec portal for booking screening appointments.
- During the appointment scheduling stage, a website for self-assessment of symptoms and guidance on what steps to take was developed by Deloitte.
- Deloitte also developed technology that integrated the steps of COVID-19 testing (making an appointment, registering, collection and transfer of samples to the laboratory). It should be noted that this system was not implemented until January 2021.
- Akinox developed the Public Health Trajectory (TSP) platform automating COVID-19 contact tracing of people who tested positive and receiving positive laboratory results via Nosotech. This enabled automatic contact tracing, supporting isolation directives and facilitating follow-up. It should be noted that Akinox developed gradually: it was initially based on manual entries and did not fully integrate the steps of case investigation until December 2020.
- At the case and contact investigation stage, the Provincial Outbreak Registry monitors community outbreaks using data provided by the regions, while the Occupational Health Information System (SISAT) allows detection of outbreaks in the workplace.

- The COVID Alert application, developed by Health Canada, notifies contacts of people with COVID-19 who use the application; however, this data is not shared with public health.
- For vaccination, Clic Santé allows people to book appointments, while SI-PMI is used to send test results.
- Following the integration of Power BI with TSP in January 2021, it was possible to visualize the total number of cases, the number of cases by region, and the affected settings by region in near real time.

Main challenges of information systems

The health and social services network in Quebec is divided into territorial networks, which in turn are divided into the CISSS and CIUSSS responsible for coordinating services. Complexities arising from this organizational model are compounded by the fact that CISSS and CIUSSS use different and incompatible IT and information systems in health establishments and laboratories. These developed in parallel, piece-by-piece in the absence of a systemic vision of integration and interoperability. The existence of different computer systems, servers and databases, alongside legacy systems, makes it difficult to extract and analyze data. The lack of system interoperability creates problems such as delays in data transfer, difficulty in updating and correcting patient contact information, along with errors and incongruities in the data and a lack of data standardization.

Given the complexity of this system, at the start of the pandemic, “pilot” IT specialists with in-depth knowledge of the different information systems had to undertake data extraction and harmonization work to be able to send integrated reports the MSSS. As a result, in the early days of the COVID-19 pandemic, the system relied on the knowledge and manual data extraction of these IT specialists, along with the arduous work of local monitoring teams responsible for producing daily reports. The development of in-house tools played a key role in managing the crisis in the early phase of the pandemic. The technical knowledge and expertise of these teams along with their organizational and human relations abilities, enabled the public health system to adapt to and transform itself through the crisis despite inadequate information systems. The resilience of public health was gravely affected by the inability of information systems to perform their surveillance function.

The use of a fragmented and non-interoperable information system limits the resilience of public health as it is not able to adequately perform its surveillance function, with limited capacity to systematically collect and analyze data and produce accurate reports. This makes it difficult to follow the evolution of disease transmission spatially and over time, understand individual transmission, identify risk factors, and make decisions to contain community transmission. The ability to prevent and detect clusters of infection and count deaths is also constrained by a lack of system interoperability.

In this way, the pandemic response accelerated the digital transformation in public health. The existence of multiple information systems operating in parallel created a jigsaw puzzle, which required urgent centralization efforts during the ongoing crisis. While at the start of the pandemic, CISSS and CIUSSS public health teams entered data into Excel files and various different databases, including the Federal Register and Computerized Medical Client File (DCMI), the implementation of Akinox TSP in April 2020 enabled investigators to begin entering data using electronic forms. The electronic forms filled out by patients were then added. Subsequently, the National Institute of Public Health of Quebec (INSPQ) began to aggregate data on positive cases for all regions in a shared database, which allowed public health teams to download reports four times a day. One of the main limitations of the Akinox TSP system is that it does not contain tracing data, which is aggregated in a separate database, the Provincial Outbreak Registry. This does not link individual cases to outbreak environments.

Human, organizational and legal factors

Public health directors play a decision-making role at strategic level for health and social service planning and response. Their work is supported by IT surveillance and infectious disease control teams within each CISSS and CIUSSS. The organization of these teams varies by region, but all have a great capacity for innovation, initiative and creativity, along with excellent technical, organizational and collaborative skills and advanced knowledge of information systems, needs and programs. Some professionals are real pioneers with considerable influence on team members. For example, a region's production of a daily report including the number of COVID-19 cases, hospitalizations, deaths and other variables requires a division of labour. One computer technician would manually extract data from the information systems, while another worked on identifying data while ensuring confidentiality; and the team supervisor guided work at a more strategic and tactical level.

Consequently, infectious disease surveillance teams were able to develop digital tools and use the tools at their disposal to be inventive and resourceful, allowing them to meet the information needs of their CISSS or CIUSSS despite technological limitations and limited access to technologies they needed.

In addition, the public health system was able to rely on close communication processes between actors at different levels. At the national level, the regional directors sit on committees created to manage the crisis in order to discuss provincial orientations; they also have daily meetings with public health directors and each directorate of the MSSS in order to discuss pandemic related issues. At regional level, the DRSPs collaborate with other directorates and external partners, including municipalities, through weekly meetings. Partnerships were also created with screening laboratories in order to tailor actions according to outbreak environments. Liaison and communication mechanisms were put in place between the DRSPs, the DGTI of the MSSS, and the IT specialists of the INSPQ.

However, due to informational issues related to patient confidentiality and computer security, the CISSS and CIUSSS infection monitoring and control teams have limited access to national public health databases. This means that teams are not allowed to open IT links in other regions and do not have direct access to TSP's database. As a result, comparison and analysis capacities are limited, as is the ability for RPHDs to develop a common vision of the pandemic.

In addition, regions have unequal access to some databases. For example, access to the RAMQ databases is restricted to CISSSs with a RPHD in their organizational chart — otherwise the RPHDs do not systematically have access to the data in the *Infection prevention control form* IT program completed by CISSS field teams to show the number of local outbreaks. Limited access to information for RPHDs also hinders teams' monitoring and analysis capacities. Finally, unequal access across regions and within regions and CISSS / CIUSSS creates inequities and misunderstandings. For example, within a same region, one CISSS / CIUSSS has access to Akinox TSP data while another does not. This problem is partly due to the lack of regulatory flexibility, as the framework was not designed to enable systems to rapidly adapt to crises.

These inequalities in data access between regions, institutions and actors risk fragmenting overall analytical capacity, in addition to hampering coordination and collaboration. In general, issues related to access to information can limit system resilience because the development of a common vision of the situation is limited by a lack of data sharing.

Resilience engages the ability of a system and its socio-technical networks to maintain or return to its desired functions in the face of disruption, to adapt to change, and to rapidly transform systems that limit adaptive capacity (Meerow et al., 2016). The establishment of collaborative networks, better coordination between actors, and a transformation of governance structures based on bottom-up and collaborative approaches are necessary to implement resilience. Building a culture of resilience is achieved by generating knowledge about risk through new technologies and by sharing this knowledge through communication, coordination and collaboration. This is why limits on access and sharing of information by regional teams, within a top-down MSSS approach aimed at protecting data confidentiality, slows system resilience, which is based on the principles of information sharing between actors at all hierarchical levels.

Conclusions and recommendations

Conceptualizing the Quebec public health system as a socio-technical system allows us to consider the way in which technologies, people and organizations interact within a system. Our research contributes to the literature on public health information systems, which is largely focused on technological issues, by integrating the study of information systems with the study of governance organizations. It shows that, despite an information system that lacked the capacity to respond to a pandemic of the magnitude of COVID-19, the capacities for adaptation and innovations of public health teams helped meet the information needs of public health decision-makers in a time of crisis, albeit at the cost of enormous human effort.

At the socio-technical level, COVID-19highlighted the absence of a common vision of information system governance able to integrate different information systems and be prepared for pandemics. The technological limits of Quebec's public health information system reflect issues related to the development of these systems around the world, in particular the difficulties in making systems interoperable, which limits the ability to produce easily integrated, good quality homogeneous data. A common understanding within the public health system of the importance of creating an interoperable information system would help to solve these problems. Doing so would include standardizing the way data is shared between systems, as well as improving their interconnection, data quality and analytical capabilities. A technological investment would make it possible to adopt new systems based on technologies capable of storing large volumes of data in real time and analyzing them by complex statistical calculations, including algorithms, as well as visualizing and sharing them in an automated manner that is secure and confidential. The availability of other sources of information, including qualitative data from the field, would also strengthen interpretation capacities.

Akinox TSP improved the centralization of public health and laboratory data. However, this platform has limited capacity to store large volumes of data, a small number of variables, and, since it is not connected to the Outbreak Registry, limits the RPHDs capacity for analysis. Following the integration of Power BI with TSP in December 2020, this system enables visualization of real-time data on a dashboard. On the other hand, while the implementation of Deloitte's technology integrated the various screening steps, it is not linked to TSP (which includes the step corresponding to contact tracing), meaning there is no real integration of the COVID-19 management process into a single tool, which would make it possible to have a common database for all stakeholders.

In terms of organizational governance, limits to information sharing are one of the main obstacles to the resilience of the public health system in Quebec. These limits result in a hierarchical relationship between the MSSS and RPHDs, and hinders the development of collaboration and coordination that are essential for resilience. Limited access to data is linked to a fragmented organizational structure and lack of regulatory flexibility that prevents information sharing at system level that would facilitate coordination, collaboration, and the development of a culture of resilience based on a common understanding of information systems, their importance and challenges. Despite the existence of adequate communication links, multilevel communication remains insufficient, hence the importance of building horizontal links between actors and of giving greater voice to local public health teams. These teams could then use their strong technical, organizational and human capacities to help design a resilient information system. The implementation of new digital tools also brings about changes in practices and involves an adaptation process. Technological development must also include greater participation from scientific circles.

The main recommendations suggested by our interviewees are as follows:

1. Improve interoperability between existing information systems. Standardize data and documents to enable data integration and better communication between systems and between regions.
2. Create a centralized database common to all stakeholders. Doing so would reduce the number of tools operating in parallel, integrate all of the data on the management process, and reduce the time it takes to obtain information.
3. Improve data storage and analysis capabilities, including predictive capabilities.
4. In order to improve TSP, it would be useful to include new variables, including socio-demographic variables, and then link them with the Outbreak Register, which would allow links to be established between cases and outbreaks in order to better understand disease transmission.
5. Include indicators to measure the response capacity of public health, including data on delays in making appointments and obtaining positive and negative laboratory results, as well as data on the number of calls received per day.
6. Collect qualitative data in the field and analyze it in order to better understand community transmission.
7. Improve support for teams in the implementation of new digital tools.
8. Improve listening skills and take the needs of local teams in