THE DEVELOPMENT OF COVID-19 DATA DASHBOARDS IN ILLINOIS: INTERACTIVE TOOLS FOR MUNICIPALITIES AND PUBLIC HEALTH PROFESSIONALS

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This study evaluates the growing prevalence of municipal data dashboards during the COVID-19 pandemic that allow users to visually track and analyze key metrics and performance indicators. It describes the expanding number of counties and municipalities in Illinois that maintain online portals and dashboards to help rapidly disseminate data about public health trends and concerns. A pair of dashboards developed at DePaul University are also reviewed to demonstrate the potential of integrating a wide body of public health data into easy-to-use analytical tools. The study concludes with practical recommendations for municipal leaders, researchers, and policymakers to help them expand their sophistication in data dashboard development.

INTRODUCTION

Many public and private institutions responded to the COVID-19 pandemic by creating data dashboards that organize and display data so that both municipal officials and the general public could stay abreast of the pandemic's trends. These online tools include customizable features that allow users to visually track and analyze key metrics and performance indicators. Many dashboards display the results of queries on color-coded maps that help users discern trends or patterns across geographic regions, such as by ZIP code, neighborhood, municipality, or county.

A consequence of the exponential leap in the development of data dashboards during the pandemic has been a heightened expectation among constituents, media outlets, and other stakeholders that the pace of data sharing and analysis will continue after the pandemic subsides. Whereas the process of collecting and evaluating data once took days or even weeks or months, many now expect municipal government and nonprofit organizations to provide vast amounts of data — and online tools to help analyze that data — with little more effort needed by the requester than making a few clicks on a smartphone or laptop. Many public officials, in turn, feel pressure to rapidly expand their in-house capacities for designing, implementing, and maintaining data portals and dashboards.

This article provides guidance for municipal governments and civic-oriented nonprofits on the development of data dashboards focused on public health outcomes. It evaluates the status of public health data on open data portals maintained by municipal governments and the rapid development of COVID-19 data dashboards throughout the pandemic. It explores the degree to which the governments of major U.S. cities, as well as counties and municipalities in Illinois, have developed dashboards focused on COVID-19 along with some of the notable budgetary and technical challenges associated with dashboard development. Attention then turns to the analytical capacities of a pair of dashboards developed by the authors at DePaul University that demonstrate the potential of integrating pandemic-related information with other public health data. The article concludes with recommendations for municipal leaders, researchers, and policymakers about ways to expand their sophistication in data dashboard development.

THE EVOLVING CHALLENGE OF DISSEMINATING AND EVALUATING DATA

The emergence of new technologies has required local governments and nonprofits to constantly change the way they provide the public with data and analysis on matters of municipal concern. Prior to advances generated by the Internet, many governments relied primarily on printed publications and photocopied reports that were sold, given away, or distributed to local libraries. Much of the information contained in those documents, invariably, was outdated by the time it reached its intended recipients.

Starting in the late 1980s, as personal commuters became more common, digital storage devices, including Bernoulli drives, floppy disks, and compact discs, helped ease the burden of data dissemination, allowing information to be released with increased speed and efficiency. Even then, a physical handoff was usually required, and using these storage devices required the recipient to have at least some computer proficiency, which was far less prevalent than it is today. Moreover, much of the data desired by the public, such as that pertaining to zoning changes and city infrastructure, were still kept in paper (analog) form, often on official maps and blueprints. Those wanting this information frequently had to visit city hall or municipal repositories to inspect it. In the City of Chicago, for example, zoning records were kept at the Municipal Reference Library, which was housed at Chicago City Hall before being moved to the Harold Washington Library after that facility's opening in 1991.

With advances in online technology, the process of data dissemination made several quantum leaps. By the late 1990s, municipal websites (and those maintained by affiliated organizations and nonprofits) were able to make large amounts of information instantly available. Initially, such geographic information was provided as static files such as Adobe's Product Document Format (PDF) or Microsoft Excel spreadsheets, but these formats were gradually replaced with more advanced downloading options. Among the most significant innovations was the growing use of geolocated files usable by Geographic Information System (GIS) software. Stakeholders could download tens of thousands of records in minutes or seconds. Interactive mapping functionality was also introduced to municipal websites. The *Illinois Municipal Policy Journal* article "Municipal Strategies for Full Lead Service Line Replacement: Lessons from Across the United States" by Pakenham, Alkafaji, and Philbrick (2019), for example, describes how governments created interactive maps to provide "real-time" information on the health risks from lead. Not all communities, however, had the resources to create such tools. Small communities still relied mostly on static documents.

Another notable step in the technology and practice of data dissemination was the development of municipal open data portals. These publicly facing online resources not only made information easier to find, but they also often included documentation concerning how and when the data were produced, as well as corresponding dictionaries for the data provided (Figure 1). The City of Chicago's portal, for example, came into being through an executive order from Mayor Rahm Emanuel in late 2012 and quickly grew to become among the country's most comprehensive municipal data gateways (Nguyen & Boundy, 2017). The Illinois communities of Evanston, Naperville, and Rockford also have public-facing municipally-sponsored open data portals. Of these three, however, only Evanston's has public health information. The development of such portals was initially spurred largely by a commitment to greater transparency and accountability. Gradually, however, the sites were used to support analytics intended to improve the quality of life and business activity in a municipality. Their existence also allowed app developers, real estate analysts, and others to tap into vast, open data sets and code to abet their commercial or civic-minded activities (Gurin, 2014).

The amount of data collected by municipal governments continued to grow spectacularly through the late 2010s. As part of the "smart city" movement, sensors measured diverse activity such as vehicle movements on streets, traffic delays, and pedestrian activity (Nyguen & Boundy, 2017). Greater amounts of crime and public health data have become available as stakeholders work to better understand and address the structural challenges facing marginalized populations. Neither municipal officials nor the constituents they served, however, had any realistic hope of properly evaluating all the data with the tools they had available, creating a pressing need for new and more-user-friendly tools.

The creation of data dashboards came largely in response to this need. Dashboards typically emphasize data visualization, often combining graphic metrics with interactive charts and maps while also providing interactive features to meet the diverse needs of constituents, civic watchdog groups, and businesses. Public agencies helped lead the push for the creation of dashboards. Recognizing the growing importance of cartographic data visualizations using GIS, for example, the Office of the Geographer at the U.S. Department of State partnered with the American Association of Geographers to host a June 2020 symposium on Cities' COVID Mitigation Mapping that contained workshops directly on the theme of "building better dashboards."[1]

LITERATURE ON THE VALUE OF PUBLIC HEALTH DASHBOARDS

The development of a data dashboard focusing on public health has come partially in response to the growing body of literature demonstrating that there is a strong link between economic inequality, income, life expectancy, and health. Most of this research was initially conducted on a national scale with little emphasis on neighborhoods within cities (Chetty, et al., 2016; Case & Deaton, 2015; and Avendano & Kawachi, 2014). Over time, more localized geographic analysis became available, much of it involving micro-scale analyses of census blocks or neighborhoods.

Long-lasting disparities in health outcomes among Chicago's diverse populations provided a strong impetus for more micro-scale analysis in

Illinois. By 2016, officials at the City of Chicago were actively discussing public health policy as part of the city's Healthy Chicago 2.0 campaign. Drawing upon information provided in the city's data portal, researchers developed metrics to better understand persistent health inequalities (Bogira, 2016). Nongovernmental networks, including Chicago's Public Health GIS Group, the Chicago City Data Users Group (which meets at Microsoft's Chicago offices), and the Smart Chicago Collaborative (now City Tech), accelerated the trajectory of analysis and pushed advanced "data analysis" to the forefront. One of us (Hague) worked with a DePaul University team in 2016 to develop a repository for maps related to public health that was also made available on the social media platform Tumblr.[2]

FIGURE 1

CITY OF EVANSTON'S OPEN DATA PORTAL — FEATURES OF LANDING PAGE

Data dashboards oriented toward public health concerns emerged during the evolution of such micro-scale analysis. Most of the early dashboards, however, were designed to support internal stakeholders of organizations. Clinicians found these tools to be useful for easy visualization and to communicate complex data and critical trends (Wu et al., 2020). One pioneering dashboard involved a hospital system monitoring catheter-associated urinary tract infections. That dashboard replaced a paper file system that was cumbersome and inconsistently formatted, as well as difficult to visually summarize, resulting in it being underutilized in published reports (Wahi & Dukach, 2019).

The crisis stemming from opioid use disorders also spurred the development of data dashboards oriented toward public health. New interactive tools were needed to better understand opioid addiction and other disorders, as well as find ways to more effectively allocate medication and supplies (Wahi & Dukach, 2019). Such needs were made evident by the HEALing Communities Study, which evaluated community-based opioid use disorder programs (Wu et al., 2020). Another benefit was to abet "data storytelling" when communicating with policymakers, the media, and the public (Wu et al., 2020).

For municipal governments, however, it was not until the COVID-19 pandemic that the development of data dashboards related to public health kicked into high gear. This accelerated pace was facilitated by the Johns Hopkins Coronavirus Resource Center, which created its own prominent and widely used dashboard during the early stages of the pandemic. The Center developed and deployed its dashboard using the "operational dashboard" template, part of GIS vendor Esri's ArcGIS online platform.[3]

The operational dashboard template was easy to deploy by those with minimal website programming experience. All that was needed was a data set, data preparation, and basic mapping experience. Such templates gained traction and "went viral" in academic communities, as well as among the general public. The Johns Hopkins COVID-19 Dashboard, for example, had received over 476 million visitors by May 2021.[4]

STATUS OF DATA DASHBOARDS AMONG MUNICIPAL GOVERNMENTS

Within a few months of the start of the COVID-19 pandemic, many local, state, tribal, and federal government entities had developed COVID-19 data dashboards that were designed for the general public's use. The analysis we provide in this section systematically evaluates the pervasiveness of dashboards among city and county governments.

DATA DASHBOARDS IN THE COUNTRY'S 10 LARGEST CITIES

Our study team explored the emergence and capabilities of data dashboards among the 10 largest cities in the United States, by population according to 2019 U.S. Census Bureau data (Table 1). Those cities are New York, NY; Los Angeles, CA; Chicago, IL; Houston, TX; Phoenix, AZ; Philadelphia, PA; San Antonio, TX; San Diego, CA; Dallas, TX; and San Jose, CA. All 10 of these cities have open data portals.

TABLE 1

U.S. CITIES RANKING AMONG THE TOP 10 IN POPULATION WITH COVID-19 DATA DASHBOARDS

CITY AGENCY	SMALLEST UNIT OF ANALYSIS REPORTED	HAS DATA BY AGE AND RACE?	CAN DISPLAY NEIGHBORHOOD SOCIOECONOMIC DATA?	MAPPING AND OTHER NOTABLE ANALYTICAL FEATURES
Chicago Department of Public Health	ZIP code	Yes	No	Maps: Historic cases, tests, deaths, % positivity cumulative or most recent week.
New York City Department of Health and Mental Hygiene	Borough and ZIP code	Yes	Yes	Maps: Positivity and testing rates over 7-day period, hospitalizations and death rates over 28-day period.
Los Angeles Departments of Public Health and Emergency Management	City	No	No	Maps: Available in individual daily report files for vaccine appts. Other: Daily data report that includes case and death data by demographic segment.
Philadelphia Department of Public Health	ZIP code	Yes	No	Maps: Testing and positivity by most recent two weeks and cumulative. Other: Data for mask compliance and severe outcomes.

Four cities — New York, Los Angeles, Chicago, and Philadelphia — developed their own COVID-19 data dashboards. Two other cities, San Diego and San Jose, are in counties that have a dashboard with city or ZIP code levels available, but they do not themselves have a dashboard. Dashboards providing county-level data are available for the counties encompassing Houston, Phoenix, San Antonio, and Dallas. None of them, however, display data down to the city or ZIP code level.

The four city-sponsored dashboards, as well as the county-sponsored tools for San Diego and San Jose, have several common characteristics. All report cumulative COVID-19 cases and deaths, hospitalization data, and testing data for geographic areas smaller than the city as a whole. The cumulative number of cases is updated daily on all the dashboards except Los Angeles, which is updated weekly. The level of detail for hospitalizations varies widely. Some dashboards, such as Chicago's, have daily availability of hospital beds, intensive care unit beds, and ventilators. Others, such as Philadelphia's, focus on hospitalization trends and cumulative hospitalizations related to patient demographics. New York and Philadelphia provide data for the type of test (molecular or antigen), but most others do not.

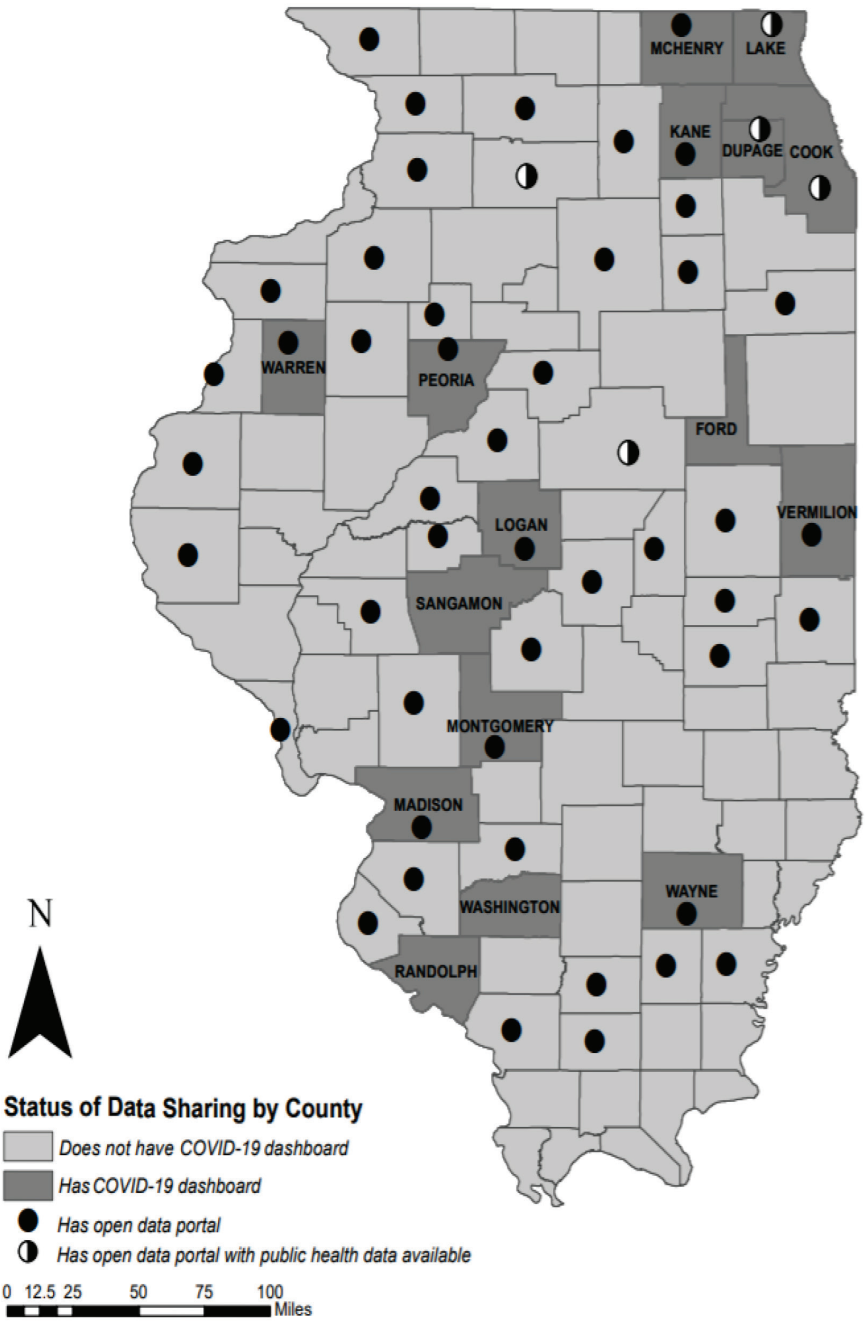
Several other differences in dashboards stand out. Most dashboards track COVID-19 positivity trends, but not all report a positivity rate. All four city-managed data dashboards include data specific to ZIP codes or census tracts. A couple of differences are also noteworthy:

- The Chicago dashboard stands out for having a menu that allows users to access a variety of detailed epidemiologic data, including case doubling rates.
- Philadelphia has statistics on mask compliance, which, according to its site, is based on security camera footage that is used to count the number of people that are correctly wearing a mask both indoors and outdoors.
- New York allows users to review data by both ZIP code and borough. The other three city-sponsored sites only allow data to be displayed citywide or in requested ZIP codes.

The results show that much commonality exists among the dashboards of major sites. Data is most commonly reported by ZIP code. Due to the tendency for ZIP code boundaries to diverge from neighborhood boundaries, however, an

FIGURE 2

STATUS OF COUNTY-SPONSORED COVID-19 DATA DASHBOARDS IN ILLINOIS



unavoidable problem on most sites is that results cannot be easily aggregated by neighborhood. For example, a Chicago resident can't easily compare positivity rates in Lincoln Park and the Gold Coast. Instead, that user would have to evaluate a variety of different ZIP codes.

STATUS OF OPEN DATA PORTALS AND COVID-19 DASHBOARDS IN ILLINOIS COUNTIES

Our analysis shows that slightly more than half (52, or 51%) of Illinois' 102 counties have open data portals, all of which make data available in GIS formats. The counties having portals tend to be more populous than those that lack them. Among 20 counties with populations more than 100,000, 40% have data portals. Conversely, only 10% of those with smaller populations have portals. The smallest counties with portals are Ford, Randolph, and Washington, each with populations less than 35,000. Five of the 52, Cook, DuPage, Lake, Lee, and McLean, provide COVID-19 data in GIS format on their data portals. Each of these has a population of more than 100,000, except Lee, which has 34,389.

COVID-19 data dashboards are far less pervasive than open data portals, being confined to 16 (15.7%) of the state's 102 counties (Figure 2). These counties are heavily concentrated in the metropolitan Chicago area and downstate jurisdictions with populations above 75,000. Eight of the state's 12 most populous counties created dashboards in response to the pandemic (Figure 3). Several counties with modest populations have nonetheless created them, including Ford (13,270) and Washington (14,052). None of the 23 counties with populations less than 12,500, however, have dashboards.

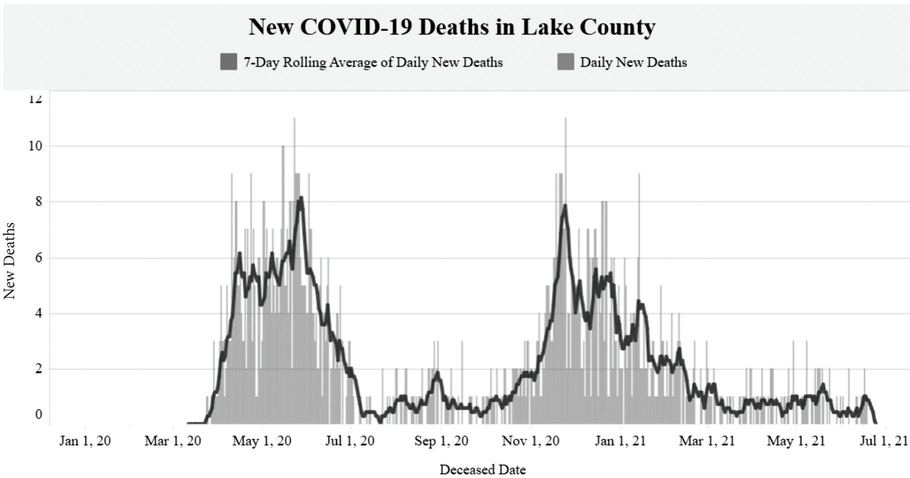
Among municipal governments in Illinois with populations greater than 75,000, excluding the City of Chicago, at least four — Aurora, Elgin, Evanston, and Naperville — have general-purpose COVID-19 data dashboards. Universities have also been active. Northwestern University has created a dashboard designed to allow users to compare COVID-19 outcomes between municipalities through the state.

THE COSTS OF CREATING PUBLIC HEALTH DASHBOARDS FOR MUNICIPALITIES

Many municipalities have faced the burden of developing and maintaining data dashboards without additional revenue to cover the costs. Although most of the data related to COVID-19 that municipalities use is available for free, there are considerable monetary costs and "opportunity costs" (the lost value

FIGURE 3

LAKE COUNTY (IL) COVID-19 DATA DASHBOARD —
PAGE DEVOTED TO DEATHS BY DAY



from activities that are forgone when an alternative is chosen) associated with developing, deploying, and maintaining a dashboard.

A particular problem is the tendency for creating a dashboard to be outside the skill set of municipal staff, especially in jurisdictions with limited resources. In response, many municipalities have turned to external consultants. For example, the City of Chicago uses Slalom, which specializes in developing online data visualization platforms that inform strategy and operations. Even when development is handled by outside professionals, however, public officials need to budget time and resources to adhere to procurement rules, which requires staff time and cross-departmental coordination, and support the multiphase process that is required for bringing high-quality dashboards to completion. This includes overseeing the dashboard's design, choosing among design options, and, in many instances "cleaning up" and transforming the data. It also typically requires beta-testing a pilot version of the dashboard prior to it being launched for broader public use.

As a general rule, we found that the various phases of dashboard development cumulatively span at least a month and, at a minimum, several dozen hours of staff time even when external consultants are involved. Similarly, while some platforms upon which the dashboards are hosted are free, municipalities seeking advanced functionality often used more specialized programs, for which costs are scaled to the amount of data that is involved. (More details about the trade-offs are discussed below.)

Another issue encountered during the pandemic are the resources required to cater to the changing needs of users after a dashboard is created. Public attention has expanded beyond case rates and mortality figures to increasingly focus on the number of vaccination sites and the types and number of doses administered. In many cases, the data needed to make enhancements requires turning to different sources than earlier versions of those dashboards. Many lightly populated counties opted not to modify their dashboards to include such information, likely due to associated costs.

Unfortunately, no general estimates of the total costs of municipal dashboards have been published. For purposes of illustration, however, consider an example showing why costs for a simple dashboard can approach $20,000 even when a dashboard is developed without hiring a consultant. If municipal workers collectively devote nine weeks (360 hours) of time to planning, developing, troubleshooting, maintaining, and assisting users, and one applies the U.S. Census Bureau's estimate of the average cost of $52.94 per hour (including benefits) for public workers, the cost in staff time alone is $19,092 (U.S. Bureau of Labor Statistics, 2020). This estimate does not include the costs of promoting the dashboard or fees for the platform used. Municipalities developing relatively sophisticated dashboards, of course, can expect to spend far more.

Online tools such as Covid Act Now, managed by the nonprofit coalition of the same name and covering the entire United States, have been developed since March 2020. The coalition's website notes that it has served 5 million website users since the start of the pandemic. As these universal sites are continuously updated, they have, in some respects, lessened the need for municipalities to develop their own data dashboards. However, these tools have significant limitations. Most notably, the raw data is drawn from centralized sources that have not been locally evaluated or quality controlled, which can make the information shared either erroneous or misleading, or both. For example, the Cook County Department of Public Health found it necessary to use a different population denominator when calculating infection and vaccination rates on account of the relatively high margin of error associated with the U.S. Census Bureau's American Community Survey's five-year estimates. Equally problematic is the fact that these universally available tools are not embedded in municipal websites that possess a great deal of additional information about the municipality's response to the pandemic. As a result, the opportunity to integrate the dashboard with local public health services and guidance is lost. Another concern is that the smallest geographic units reported on most general sites, including Covid Act Now, are counties, which prevents neighborhood-level analyses. Despite this, municipalities should welcome the creation of universal websites, which may have sophisticated analytical features providing new ways to educate the public.

UNIVERSITY COVID-19 DATA DASHBOARDS

The above analysis makes it clear that most data dashboards have limited functionality beyond providing basic information regarding COVID-19. Currently, few dashboards provide features that allow users to drill down and explore the interplay between the virus and other public health concerns, such as vulnerabilities facing particular neighborhoods or populations. In response to this community need, as well as the need to understand the demands of training public and nonprofit officials about creating dashboards, DePaul University has created two dashboards. Each experimented with additional functionality and data-analysis features that are not available on other Illinois sites. We briefly describe each below.

CHICAGO COVID-19 HEALTH EQUITY DASHBOARD

This DePaul dashboard, focused on health equity, was created to fill a critical need and beta tested starting in September 2020 (Figure 4). This site uses Esri's classic ArcGIS Dashboards platform, with much of the data processing and analysis carried out using the "R" statistical package with the corresponding data processing code and GIS layers made available via GitHub.[5]

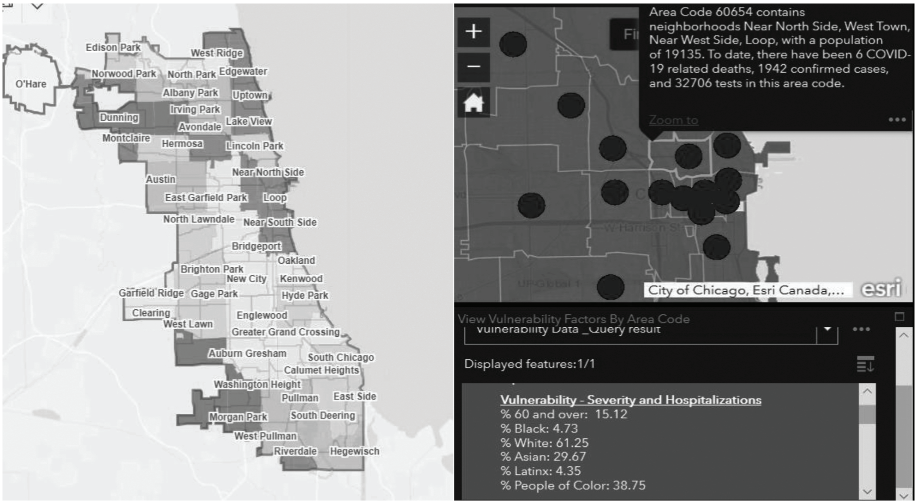
The welcome page combines municipal, county, state, and nationwide trends from multiple data sources to provide easy-to-digest charts of COVID-19 cases, deaths, and vaccinations for the city, while also providing comparisons to Cook County and the United States as a whole. The results are presented daily and cumulatively using a seven-day moving average. This provides meaningful context for neighborhood-level information presented in subsequent tabs.

The dashboard has tabs that take users to specialized sections on health trends, vulnerabilities, and disparities. Four additional features of the dashboard serve as prototypes for future dashboards:

FIGURE 4

UNIVERSITY COVID-19 DATA DASHBOARDS

Public Health Equity Dashboard | Custom Dashboard



DePaul's Chicago COVID-19 Public Health Equity Dashboard (left) generates color-coded maps that allow users to compare the pandemic's burden across ZIP codes on the basis of their quintile rank. The Custom Dashboard (right) has a pop-up feature that summarizes key outcomes by ZIP code.

- **Color-coded visualizations of neighborhood differences.** The dashboard uses a system of color-coding to show differences in risks and outcomes between neighborhoods. Users can toggle to watch week-by-week changes across the city's 58 ZIP codes unfold on a map for variables such as COVID-19 positivity, infection, and mortality. The color coding is based on the quintile in which the ZIP code falls. For example, dark red represents those ZIP codes suffering the greatest burden (i.e., in the top quintile), based on the distribution of outcome since the beginning of the pandemic. Dark blue represents values in the bottom (or lowest) quintile. Users can watch how the dark red shading moves around the city during different phases of the pandemic.

- **Clustering of disease incidence.** The incidence of the disease and rate of positivity (i.e., "hot" and "cold" spots) are calculated, clustered, and mapped using R's spatial analysis package (Bivand & Wong, 2018). These clusters (or, more precisely, local indicators of spatial association scores) help identify statistically-significant geographic groupings of communities facing low and high burdens (Anselin, 1995).

- **A Relative Hardship Index.** One factor considered essential to understanding the distribution of COVID-19 cases in Chicago was the development of a Relative Hardship Index. It provides a comprehensive measure of the COVID-19 burden by considering outcomes during the entire pandemic, as well as during recent weeklong periods. The Relative Hardship Index was created in 2020 to help immediately support mobile testing units. Resulting from the DePaul data dashboard developers' participation the City of Chicago's Racial Equity Rapid Response Team, the index was computed using equally weighted standardized scores of a variety of weekly metrics: test positivity rate, case rate, and death rate together with week-over-week point changes of those same rates. The Relative Hardship Index, therefore, gave public health practitioners a metric that encompassed new cases in an area alongside that area's general public health problems throughout the course of the pandemic. By evaluating both week-over-week changes and overall public health concerns, the index provided a useful starting point for mobile units to assess priorities. One limitation, however, is that the study team was not able to develop weights for each of the variables. Weighting these weekly metrics would be possible in the future as more knowledge about the spread and virulence of COVID-19 emerges.

- **Measures of disparity and inequity.** The dashboard has built-in features that allow the user to assess and compare COVID-19 vulnerability and disease outcomes across different demographic groups, including comparisons by race and ethnicity. These features help address the growing pressure on counties and municipalities to address public health inequities, which have been defined as "systematic, unfair, and avoidable differences in health outcomes and their determinants between segments of the population" (Penman-Aguilar et al., 2016, p. S33).

The resulting dashboard supported DePaul's collaborations with the City of Chicago and helped strategically identify where mobile or pop-up COVID-19 testing sites were most needed. It also helped the Racial Equity Rapid Response Team better understand emergency response needs in different parts of the city.

CUSTOM DASHBOARD USING THE ARCGIS WEB APPBUILDER

The Custom Dashboard was completed between January and June 2021, six months after the Health Equity Dashboard. It was designed to overcome limitations of the operational dashboard template used by the Health Equity Dashboard, which has a streamlined design but is quite limiting when it comes to adding or customizing features. For instance, the operational dashboard template does not allow code to be downloaded and rehosted online, and any dashboard created must be linked to ArcGIS's online cloud hosting. These limitations are being gradually resolved, but they are still significant.[6]

Another issue was that since the ArcGIS operational dashboard is an Esri licensed product, every time a site hosting an operational dashboard is hit by a viewer, the host must pay hosting and licensing fees to the owner. In other words, the dashboard cannot be hosted by an organization's own infrastructure and server. Nor can operational dashboards be "extended," meaning that the underlying code cannot be adjusted to give a dashboard additional features. Any dashboard's visualizations and features, therefore, are limited to those provided in the operational dashboard template. Additionally, support for automatic updates through scripting languages is limited, meaning that manual updates of the initial dashboard are necessary.

For this reason, the DePaul team created a Custom Dashboard with additional features, including tools that allow for a wider range of charts and maps to be created in response to user needs. Creating a dashboard using the Web AppBuilder platform made available by Esri also provided a few other advantages:

- **The core functionality of the popular operational dashboard template could still be made available with drag-and-drop support for charts and interactive maps.** As a result, many of the same features from the initial Health Equity Dashboard could be integrated in the Custom Dashboard.

- **Web AppBuilder allows code to be changed and rehosted.** This means that a second Custom Dashboard iteration can be extended with code and then rehosted on an internal organization server. Web AppBuilder, together with JavaScript code, supports wider date ranges, as well as features that allow users to focus on particular neighborhoods and other parameters.

With these changes, a user of the Custom Dashboard can alter the display of content in response to input regarding desired data sets, date ranges, and geographic location.

KEY COMPONENTS OF STUDENT AND WORKFORCE TRAINING

As the above analysis suggests, government and nonprofit agencies will face pressure to acquire in-house expertise to respond to the need for data dashboards. To understand the best ways to impart such expertise, one member of the research team (Follett) taught a WebGIS course in spring 2021 in which graduate and undergraduate students were trained to evaluate and create dashboards. Five lessons are relevant to municipal governments seeking to expand their skills in dashboard creation:

- **A starting point for training is assuring students understand the trade-offs between ready-made templates versus customizable interactive web map products.** Learners must understand the different advantages and disadvantages of each approach, both with respect to the labor involved and customizability. As part of this, we also emphasized how no data set is neutral. Data sets carry the legacy of how they are collected and gathered and structured before they are interpreted. Furthermore, some degree of data cleanup is almost inevitably necessary.
- **Instruction about customizable dashboards needs to include coverage of several web programming languages, including HTML, JavaScript, Python, and Cascading Style Sheets (CSS).** Learners must explore firsthand how web design and web programming languages define the limits and potential of web-based GIS mapping products. In the class, we evaluated DePaul's two COVID-19 dashboards to illustrate what is possible using different programming languages.
- **Requiring students to create and host their own dashboard, even with a limited number of features, is essential to help them understand the extensive troubleshooting that is involved.** This exercise challenges participants to explore the usability of their creation, as well as consider its intended audience. We asked that learners explore different possible designs for interactive maps while imagining someone other than themselves using the product. Our activity was modeled after human-computer-interaction methodology

and related principles regarding accessible design and interaction (Wickens et al., 2004).

- **Training should include an emphasis on visualization skills that allow for comparative analysis.** Learners should be given the challenge of building interactive maps that lend themselves for comparative analysis, as well as generate time-series animations. Instructors need to stress the importance of a user-friendly interface for interactive maps that are aimed toward a nontechnical (general) audience. Learners must understand the importance of tweaking and adjusting interactive map products in response to user feedback or contextual limitations of time and resources. Many students found Leaflet Storymaps, an increasingly popular online visualization tool, to be particularly beneficial.

- **Multilingual capabilities should be given priority.** Among the insights learners generated was that for non-English speakers, the automatic translation of certain parts of the dashboards was inconsistent.

Another challenge is finding ways to reduce the risk that the data provided in a dashboard will be misused or misconstrued. Dashboard developers need to devote attention to conveying the pitfalls of measurement error and ascertainment bias (e.g., distortions that can occur when collected data is more likely to include some members of a population than others). Similarly, those using a dashboard need to be informed (or reminded) about how confounding variables can make it difficult to draw inferences from the data. The study team found that when working with students, their desire to impress users with graphics — often without proper recognition of the need to help users understand what the data actually show — was a persistent problem.

CONCLUSIONS

The COVID-19 pandemic is raising expectations that municipal leaders prioritize the rapid dissemination and evaluation of data related not only to public health but other aspects of municipal life, as well. It behooves both public entities and nonprofit officials to take steps to expand the in-house skills of their administrative units to enhance online data portals, data dashboards, and other tools. Our analysis shows that county governments and large municipal governments have made strides in creating data dashboards that give the public, constituents, and other stakeholders the ability to quickly and easily evaluate COVID-19 outcomes. County governments in Illinois have been quite active in this regard, in part due to their tendency to have greater staff resources devoted to public health departments than municipal governments. A wide range of data dashboards emerged within a few months of the start of the pandemic, showing how governments can — even when facing much financial and administrative adversity — innovate in the midst of an emergency.

Most dashboards created by county governments in Illinois are stand-alone tools that are not designed to be enhanced to allow other public health problems affecting communities to be evaluated. Few county-created dashboards have features that allow the disparate impacts of the pandemic on various population subgroups and neighborhoods to be systematically evaluated. In our view, the next phase in dashboard development should emphasize the creation of more versatile tools that are able to show a wide range of public health outcomes against the backdrop of varying levels of health-care access, vulnerability, income, and other variables. This will require a heightened degree of technical sophistication.

A challenge facing municipal governments is the need to evaluate the trade-offs between using ready-made tools, such as the ArcGIS operational dashboard template, and more specialized but time-consuming approaches when developing public-facing dashboards, as we did when creating DePaul's Custom Dashboard. While grappling with such trade-offs, it is critical that local officials appreciate the impossibility of anticipating what new challenges will be created by the next crisis. This makes the creation of data dashboards imperative, so they are adequately prepared.

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ENDNOTES

1 Information about the Cities' COVID Mitigation Mapping project, with a link to the webinar on the project, can be found at https://mapgive.state.gov/c2m2/.

2 This series of maps examining life-expectancy in Chicago is available at https://chicagolifeexp.tumblr.com/.

3 Information about the Esri platform is available at https://www.esri.com/en-us/arcgis/products/arcgis-dashboards/overview.

4 Information about the Johns Hopkins dashboard is available in this Fierce Healthcare article, dated May 21, 2021, and available at https://www.fiercehealthcare.com/tech/johns-hopkins-medicine-became-information-powerhouse-during-covid-19-pandemic-here-s-how. Additional information on the Johns Hopkins dashboard can be found at https://coronavirus.jhu.edu.

5 This GitHub repository, by C. Scott Smith, can be accessed at https://github.com/justenvirons/covid-dashboard.

6 Some of the recent enhancements are discussed in an ArcNews article from summer 2021, available at https://www.esri.com/about/newsroom/arcnews/new-dashboard-technology-now-widely-available/.

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