TRAPS - A Visual Analytics System for Public Health Surveillance

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Abstract

This article proposes a visual analytic framework for monitoring and evaluating preventive health programs. The Centers for Disease Control and Prevention (CDC) developed an evaluation framework that focuses on a set of guidelines for public health professionals to evaluate public health programs. This article underlines a growing need for a visual analytic framework to support public health professionals with tasks related to managing programmatic activities and helping them monitor and evaluate ongoing efforts to plan for future programs. Visual analytic frameworks are conceptualized to address domain-specific tasks that equip domain experts with analytical reasoning to make better decisions. We present the Tobacco Reporting and Progress System (TRAPS), a visual analytic system used for managing and evaluating tobacco cessation programs in Mississippi. We assessed the TRAPS data portal based on user logs and the program evaluator's observations utilizing the system for evaluating tobacco control programs. The TRAPS data portal could also be used to help monitor and report other preventive public health programs with similar needs.

1   Introduction

Health agencies develop programs to support their community's well-being by examining existing public health needs and statewide resources. According to the CDC, public health is defined as "the science of protecting and improving the health of people and their communities. This work is achieved by promoting healthy lifestyles, researching disease and injury prevention, and detecting, preventing, and responding to infectious diseases", whereas public health surveillance is defined as "the ongoing, systematic collection, analysis and interpretation of health-related data essential to planning, implementation, and evaluation of public health practice"[5].

Public health professionals and executives often strategize public health intervention programs for better health outcomes. Each public health program encompasses several activities targeted towards the population in need. There is a growing need for understanding the effectiveness of these programs to improve the intervention outcomes of state agencies' programmatic

efforts. We believe the insights gained from program evaluation will help agencies make better policy decisions in addressing public health needs.

We propose the Statewide Programmatic Activity (SPA) framework to elicit system requirements for evaluating health programs. We then map health professionals' tasks with program evaluation requirements such as information management and data analysis of statewide programmatic data. We introduce TRAPS, a visual analytics system used by program evaluators and public health professionals for monitoring and evaluating tobacco control programs. TRAPS is designed to support high-level tasks such as information management and data analysis of statewide programmatic data. We evaluate the tool based on the user activity and the program evaluator's observations about the tool's ability to meet the requirements specified in the SPA framework. The knowledge gained from evaluating this tool will further promote research in the field of visual analytics for public health, thereby helping public administrators use these efforts for similar preventive public health programs.

2   Related Work

Visual analytics is a concept that involves human participation in the data visualization process to extract meaningful insights. It can be defined as "the science of analytical reasoning facilitated by interactive visual interfaces"[8, 27]. With the exponential growth of data generation and storage, humans are finding it increasingly difficult to analyze it effectively. Visual analytics has emerged as a solution to this problem by enhancing human cognitive abilities to analyze vast amounts of dynamic and diverse data. This domain is a fusion of visualization, statistical analysis, and data mining techniques, tightly integrated with human analytical and decision-making abilities. Visual analytics aims to help analysts gain insights into complex datasets by providing interactive visual interfaces that facilitate the analytical reasoning process. It is an iterative process wherein the analyst must be involved in the decision-making loop and pose relevant inquiries to gain deeper insights into the data.

Visual analytic frameworks are often conceptualized to address domain-specific tasks to equip domain experts analytically to make better decisions. Healthcare analytics is the field that deals with providing analytics to both patients and the provider using electronic health records [26], based on information related to patients. While there are numerous such efforts in health care analytics, we haven't found similar efforts that addressed the needs of state agencies for managing, and analyzing their statewide programmatic activities related to public health, safety, and well-being. In 2020, Preim and Lawonn [20] conducted a comprehensive survey on visual analytics for public health. This survey highlighted the need for a visual analytic framework for public health surveillance and intervention. In 2022, Christie et al. [6] performed another comprehensive survey of interactive visualization applications in population health and health services research. They identified a few applications related to epidemiologic surveillance for infectious disease [7, 4], health service monitoring [16, 21, 13], planning [14], or quality [19]. Ola, et al. [1] listed opportunities and challenges of big data in public health, while Brownson et al. [3] work highlighted the need for evidence-based decision-making in public health.

There are a considerable number of visual analytic tools used for surveillance of air quality data [9, 22, 15], infectious disease [2, 12, 18], and chronic diseases [23]. While there are business intelligence tools such as Tableau [17], PowerBI [10], and Qlikview [25] to help analysts explore, visualize, and present information. The features and capabilities provided by these tools are inadequate to address the needs of statewide program managers to manage and analyze information related to their programmatic efforts.
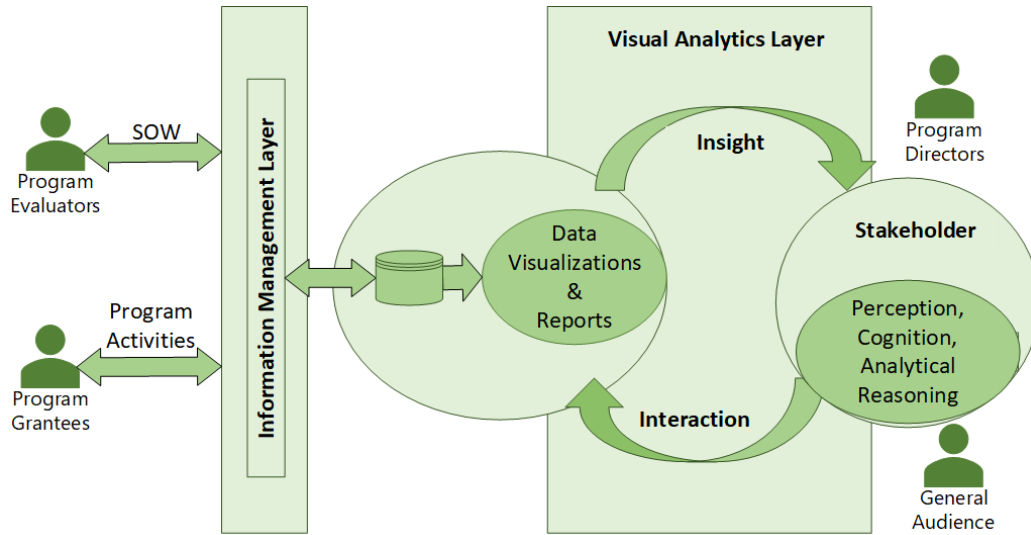
Figure 1:   Statewide Programmatic Activity (SPA) framework, with stakeholders and tasks related to program evaluation.

3   Statewide Programmatic Activity Framework

In this section, we identify stakeholders and a set of requirements and tasks needed for developing the analytics system for state agencies to manage their programmatic activities. As part of this process, we identified system stakeholders and coordinated with them to better understand their programmatic requirements. While some of the evaluation requirements for health programs are similar, the deliverables or the scope of work (SOW) differ for each statewide program. Program evaluators, grantees, and directors are three broad sets of system users who need access to the system to perform a set of tasks to satisfy the following requirements, as noted in the list below.

As shown in Figure 1, we propose the SPA framework designed to fulfill the following requirements,

1. System's ability to accommodate multiple programmatic activities and categories.

2. System's ability to accommodate programmatic activities at the state level, county level, or coalition level, which is based on a group of counties.

3. System manager's ability to add and update programmatic activities, and share resources for program grantees.

4. Program grantee's ability to add, review, and change recorded activities.

5. Program supervisor's and evaluator's ability to monitor program progress.

6. Communication between stakeholders.

7. Visualizations to analyze activities across time, geographic regions, and community groups.
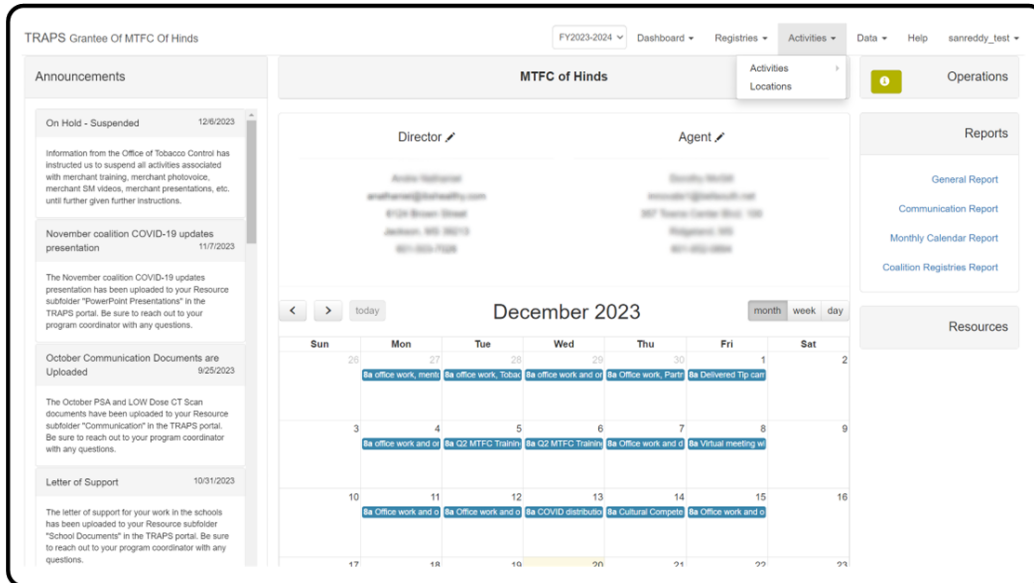
Figure 2: TRAPS dashboard overview of the MTFC grantee of Hinds, located in central Mississippi. The details of the program director and the fiscal agent were blurred to protect their privacy.

8. Ability to retrieve static and dynamic reports.

Program evaluators use the information layer to manage the SOW progress, while the program grantees interact with the information layer to feed and manage their programmatic activities. The information layer is then coupled with the database for storing and retrieving information as needed. The visual analytics layer lets system users query the database interactively for better insights. These insights on programmatic activities have a spatial and temporal component, hence the need for context-based visualizations. The interactive visualizations enable stakeholders to examine programmatic activity insights and then, based on the task requirements, use analytical reasoning to pass further queries using interactions to explore the changing level of details in a continuous loop.

Overall, the SPA framework was developed for preventive health programs in coordination with the requirements of tobacco control programs. This framework potentially benefits state agencies in improving their data collection methods, improving data quality and accessibility for better decision outcomes [28], [24], [11]. The software template built to address these requirements helps other preventive health programs by reducing the time and cost required to build health information systems for effective evaluation and surveillance of preventative health programs.

4   Tobacco Reporting and Progress System (TRAPS)

The Mississippi Tobacco Data (MTD) team at Mississippi State University developed the TRAPS data portal to help evaluate programs and services administered by the Office of To-

Figure 3: All four figures plot activities for the MTFC of Hinds County located in the Central Mississippi region. 1. The top-left pie chart shows the number of activities. 2. The top-right plots the number of events across multiple locations. 3. The bottom-left represents the longitudinal trend of selected activities. 4. The bottom-right treemap shows the number of distributed items in a given fiscal year.

bacco Control (OTC) at the Mississippi State Department of Health (MSDH). The data portal allows program monitors, executive directors, program officers, and evaluators to review all programmatic activities and their progress yearly, quarterly, and monthly.

Each fiscal year, the system evaluators work with program directors to derive measurable goals for activities within the SOW. This process ensures the SOW deliverables have measurable outcomes that can be evaluated in a meaningful way. The current grantees start recording their activities starting July of every fiscal year, lasting until the end of June of the consecutive year, while other grants use the federal fiscal year. TRAPS is adaptable to either. Evaluators then pull activity reports to evaluate grantees' activities of all programs hosted in the TRAPS database at the end of each fiscal year.

TRAPS is scalable to accommodate data related to multiple health programs, each with a different SOW. These activities are then entered into the system by TRAPS evaluators so grantees can report them. Since 2014, TRAPS captured data for four cessation control programs, 34 Mississippi Tobacco-Free Coalition (MTFC), four systems change programs, and four youth initiation prevention programs. In 2024, TRAPS has managed upto 44 program grantees, including 34 MTFC grantees. There are four regional branch directors overseeing the 34 MTFC grantees. Each MTFC grantee's area of coverage includes one, two, or three counties, determined based on the population size in those counties. While MTFCs are limited to the coalition region, all other programs are statewide.

Figure 2 shows the dashboard overview of an MTFC program grantee with access to a
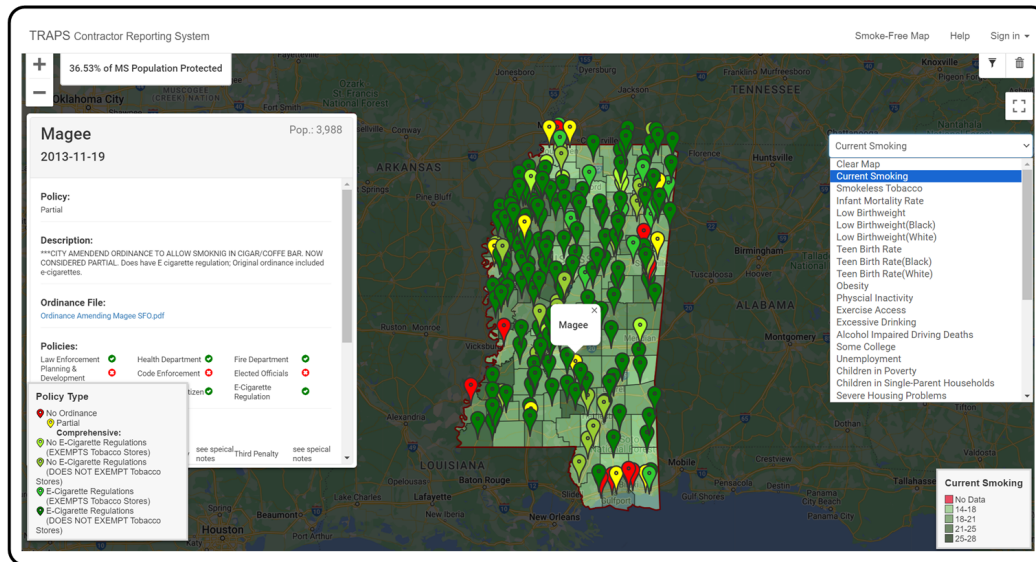
Figure 4: Smoke-Free map with each glyph representing smoke-free ordinance type and layered with current smoking rates in the background.

calendar to record itineraries with an announcements section on the left. Calendar entries help program directors have real-time access to grantee activities, location, and contact information, enabling them to attend the event anywhere across the state.

The panel to the right of the dashboard contains three folders: Operations, Reports, and Resources. The Operations folder is crucial in collecting documents from program grantees to support programmatic activities such as training sessions, meetings, events, presentations, and expenses submitted for reimbursement by grantees. System users can use the Report folder to generate reports for evaluation based on their role. The Resource folder allows the system managers to share documents that remain available for the fiscal year with the grantees. Its robust tracking interface enables program grantees to access the data portal from any location to add and change data related to their programmatic activities. It provides the ability to measure specific program outcomes by state, region, or county to define and refine program validity.

As shown in Figure 3, the system users can access yearly trend charts, activity charts, distribution charts, and activities maps. The yearly trend charts provide insights into activities across years, while the activity chart is a pie chart of activities for a given year. The drill-down feature in the pie charts allows program directors to focus on a single group's activities, while the overview presents insight into the number of activities performed by the health groups. The distribution chart maps the number of distributed items like educational materials or incentives for the activities. The data map presents spatial insights on the number of activities in all activity locations for a given selected year based on their role. The glyph color is used to represent the number of activities, while the background county layer color represents the selected population health measure sourced from the county health rankings report. This map helps users to gain insights into the relationship between the number of activities performed and the county-based population health measures.

As shown in Figure 4, the smoke-free map is similar to the activities map. In this map, glyphs represent the smoke-free ordinances across Mississippi. The glyph color is used to describe the smoke-free ordinance type, while the background color of the county layer is mapped with demographic variables such as current smoking rates. These maps are for the general audience and policymakers to understand the impact of tobacco-free control programs based on the smoke-free ordinances passed across the state and their relationship with population health measures.

5 Evaluation

This section explores the grantees' and program evaluators' experiences using the TRAPS data portal to perform tasks fulfilling the requirements listed as part of the SPA framework. We use quantitative data, such as system logs, and qualitative observations to evaluate the data portal.

As shown in Figure 5, the system logs were used to assess TRAPS usability from the grantees perspective based on user interactions with the system. The bar graph shows the frequencies of program grantees actions, such as signing into the portal, and pulling reports to perform their tasks for the last seven years. Since we have fewer than three program evaluators in any given fiscal year, we report their qualitative observations to evaluate the system's effectiveness from their perspective based on the following two questions.
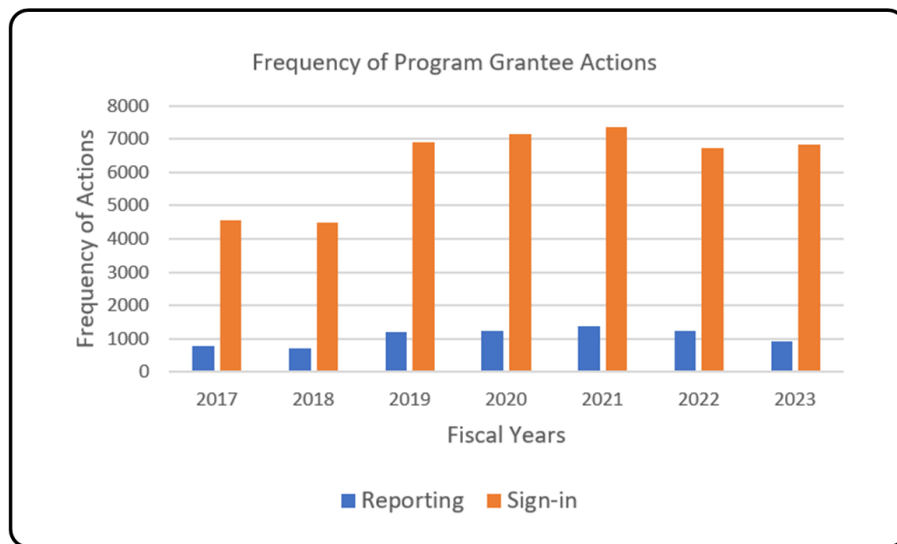

Figure 5: TRAPS Program Grantee Actions for the last seven years.

How has TRAPS improved data quality? The grantees used paper records to record their programmatic activities before using the data portal. In most cases, the collected data was incomplete, making it challenging to piece together activities conducted, people reached, items disseminated, dates, and other details surrounding the programmatic activities. It was cumbersome for program evaluators to find a complete picture per quarter, let alone a year-end report with validity based on the data collection methods used before deploying TRAPS. The TRAPS data portal allowed program directors and evaluators access to programmatic data and connect

stated activities with supporting documents uploaded to the operations folder for validation. This may include sign-in sheets, agendas, meeting minutes, and training evaluations. The system helped promote financial transparency as the program funders can ensure they are paying invoices and travel expenses to grantees based on proven activities. More so since the portal includes a calendar that can be used as a tool in coordination with the collected programmatic data.

How did insights from charts and maps in TRAPS help program directors and evaluators make better decisions? The ability to visually see the data is valuable to the grantees as well as supervisors, funders, and evaluators since a table can show what activities occurred, how many people were reached, how many educational resources were shared, and how many of said activities happened in the time frame noted. The portal allows the user to query by month, quarter, region, program, and year.

System users used the interactive pie chart to gain insights into the number of activities performed by each coalition group. The users were able to interact with the pie slice representing the coalition, which then enabled the pie slice to become another whole pie, broken out per activity for the selected coalition. This is an example of the dynamic aspect of charts and maps that help users perform tasks efficiently. The spatial mapping component based on the activity data recorded by each program grantee pairs with the tables, charts, and data analysis, thereby helping evaluators manage data quality.

Overall, this system allows the Office of Tobacco Control to monitor and provide short-term, intermediate, and long-term health intervention outcomes to influence program and policy direction, ensure accountability, and demonstrate effectiveness through its surveillance and evaluation capabilities.

6   Discussion

As visual analytic systems for public health data continue to evolve, studies on the impact of such tools on analysis accuracy, speed, and decision-making are warranted. Health information systems like TRAPS can aid public health professionals in monitoring and evaluating interventions with data collection methods that improve programmatic data quality through the aggregated views of statewide activities. The ability to perform cross-program and temporal analyses in TRAPS promotes data-driven decision-making to improve strategic planning and, therefore, population health.

In the future, we plan to use additional evaluation methods, such as usage analytics, think-aloud protocols, and benchmarking against similar systems, to evaluate TRAPS. This effort can inform future research on development and assessment of visual analytics for public health surveillance. As the adoption of platforms like TRAPS increases, issues of data quality, data security, and governance will need attention. Overall, this system could serve as a monitoring and reporting venue for other public health programs with similar preventive health programming needs.

7   Acknowledgements

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