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A FRAMEWORK FOR EVALUATING NON-HEALTH
TECHNOLOGY FOR APPLICABILITY WITHIN PUBLIC HEALTH

BY

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M.P.H, Emory University, 2014
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An abstract of
A Thesis submitted to the Faculty of the
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Abstract

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The existing literature has many valuable frameworks for evaluating public health informatics systems. The existing frameworks provide a useful set of valid attributes and measures for determining the value and impact of a system within a public health organization or community. However, emerging tools and technologies are developed outside of public health that may be of value within public health informatics systems or as stand-alone tools used by public health practitioners. These tools need to be evaluated as stand-alone components to be included, if useful, within public health information systems and practice.

This research seeks to extend the available methods for public health informaticians to evaluate particular tools, approaches, practices or non-public health systems for their viability of use within public. While much software exists outside of the public health and health information technology domains, it is important to evaluate potentially useful tools based on the characteristics important for public health. This study performed a systematic review of the public health literature to determine commonly used attributes for evaluation, harmonized them into a common set of attributes appropriate for evaluating technology and created a simple tool for performing and documenting evaluations.

Thirty-two attributes are commonly occurring within the health literature, analyzing frequency and harmonizing these attributes for generalizability in evaluation of technology outside of health and public health led to the selection of nine attribute concepts that are most useful to evaluations: Acceptability, Usefulness, Accuracy, Architecture, Data Quality, Timeliness, Costs, Organizational, and Supportability. Thirteen additional attributes may be useful depending on the judgment of the evaluator: Data Management, Data Analysis, Documentation, Performance, Flexibility, Stability, Data Dissemination, Standardization, Security, Simplicity, Portability, and Ethical. Additional attributes can be included based on the judgment and determined need of evaluators using the tool within their organizations.

Using these attributes this study developed a method for evaluating technology, a template for use by informaticians, an example evaluation using the template and a method to represent evaluation results in a reusable JSON data structure.

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Chapter 1: Introduction

Introduction and rationale

The existing literature has many valuable frameworks for evaluating public health informatics systems and specifically public health surveillance systems. Foremost, and most recent, is Buehler et al's 2004 framework for evaluating public health surveillance systems [1]. The existing frameworks provide a useful set of valid attributes and measures for determining the value and impact of a system as a whole within a public health organization or community. However, emerging tools and technologies are developed outside of public health that may be of value within public health informatics systems or as stand-alone tools to be used by informaticians and other public health practitioners. These tools need to evaluated as stand-alone components to be included or excluded within a public health information system [2]. This research seeks to extend the available methods for public health informaticians to evaluate particular tools, approaches, practices or non-public health systems for their viability of use with public health practice and information systems. While much software exists outside of the public health and health information technology domains, it is important to evaluate potentially useful tools based on the characteristics of public health and the needs of public health practitioners.

Technology tools can have a positive impact on public health practices and systems when properly planned and integrated into public health practice [3]. But the determination of fit for technology is highly dependent on organizational structure, interaction with other components of a system and potential reuse. The system planning and design of an information system involves a mixture of new software components and subcomponents while also integrating existing components and techniques. While the proper selection of a tool will extend the functionality of a system or process, the inclusion of an inappropriate tool can have immediate or long-term detrimental effects [4].

Public health information systems are frequently developed using external tools and technology systems [5]. The architecture of a particular information system needs to include in its design not only new developed components used specifically for public health, but existing technologies such as general purpose programming languages such as Java and Ruby on Rails, relational database systems such as Microsoft SQLServer, MongoDB, and MySQL [6], and statistical analysis tools such as SAS and R. The appropriate technology selection will depend on the specific functional needs of the public health information system as well as the organization where the technology is to be used [7].

The selection of appropriate fit technology becomes more complex for public health practitioners without experience in informatics as they may not have experience with attributes that are not detectable on initial use, but may have long-term negative effects on the continued use of the tool [8]. If informaticians create evaluations of tools using a structured approach and shared evaluations within the public health community, non-informaticians can discover and more easily assess tools for their applicability within their own organization and public health processes.

This research aims to conduct three novel tasks:

- Perform an extensive search and systematic review of the public health informatics literature in the area of system evaluation that can be applied to technologies not designed for public health.
- Identify a set of common and applicable attributes and measures that are harmonized for use in evaluating non-public health technology
- Design a structured evaluation tool template for use by informaticians to assess non-public health technologies

Problem statement

The literature currently contains sound guidance for evaluating public health and healthcare information systems [1, 7, 9-11] to provide guidance and structure for assessing entire systems for impact. However, technologies exist outside of dedicated, purpose-built public health systems that can be useful components within systems or components within a public health workflow. The literature contains indicators, attributes and measures specifically used for public health evaluation that can also be applied to technologies, tools, and approaches that will help to determine whether a tool is useful for public health practitioners and informaticians.

By assessing appropriate attributes and developing an evaluation tool that can be used beyond public health informatics systems, this research seeks to improve the rate at which new techniques are brought into public health from outside domains. Inappropriate technologies introduced into public health can detract from the efficiency and effectiveness of public health [12]. Choosing appropriate technology and tools is needed to improve the adoption of health information technology. If translated effectively into public health informatics, technology will help not only public health practitioners, but also non-informatics public health practitioners who are most frequently the users of such new approaches.

With a set of evaluation tools for smaller components rather than entire systems, informaticians can more easily share results of evaluations. If results can more easily be shared, then results will be more widely available to assist system designers in the selection and use of new technology within their system planning procedures. In the creation of informatics systems, system designers will be able to review and select specific components from outside of public health to assist in the architecture and planning of what needs to be built anew, rather than reused or modified for reuse.

The risk of incorrect or inefficient selections is high for system designers and program leads working with system designers. Being able to collect together lessons learned from each tool or component evaluation will help to reduce the risk of system mismatch and increase understanding and use of the technology [13].

Theoretical framework

This study is a hybrid between the subjectivist research evaluation study approach art criticism approach and the objectivist research evaluation study approach of the comparison based approach technique [14]. The criticism approach relies on an informatics subject matter expert (SME) to systematically review existing literature for attributes used in the evaluation of public health systems and extracting data from each review that used one or more defined attributes as part of its evaluation. The comparison approach reviews the extracted attributes to identify clusters of commonly used attributes based on their use within the matching articles and papers. Again, both approaches will be used to develop a structured tool that can be used depending on the level of effort available to the informatics practitioner and the potential significance of the tool used within public health.

Purpose statement

Informatics will benefit from a detailed structured evaluation tool for technology, tools and approaches that examines potential impact within public health systems and programs. This tool should use well-defined attributes appropriate and useful to public health that guides informaticians and reduces time necessary for a useful evaluation. The output of the tool should be able to be discovered and reused by other informaticians with similar questions and needs as well as non-informaticians trying to determine tool fit within their organization and systems used.

Study objectives

This study focuses on three specific objectives:

- Objective 1: Perform a systematic review of published public health informatics evaluations of systems, tools and approaches.
- Objective 2: Identify commonly used attributes within evaluation literature and develop a harmonized set of evaluation attributes suitable for use with non-public health technologies

- Objective 3: Develop a structured evaluation tool template that can be used to evaluate non-public health technologies for potential impact to public health

Significance statement

Tools and technologies are currently evaluated based on how they improve public health practice as part of public health information system design. These evaluations are carried out in various manners by informaticians and non-informaticians alike. Evaluations are sponsored by organizations responsible for carrying out public health functions such as surveillance and epidemiology and typically have the specific needs of the organization and surveillance system in mind as part of the evaluation [1]. Each organization has specific contexts and needs that influence the applicability or fit of a technology within the systems of that organization. As a result, the findings from one evaluation may not be useful to programs outside of the immediate domain of the initial evaluation. By providing a structured evaluation tool that seeks to reduce or remove the biases of each evaluator, results can be captured and shared in a manner that allows for greater reuse including use by public health practitioners with minimal training in public health informatics.

Over time, the output created by evaluators using this tool will allow public health practitioners to compare evaluations of similar tools and make an informed selection without being forced to repeat an evaluation.

Definition of terms

Term	Definition
Architecture	"…a systematic approach that organizes and guides design, analysis, planning, and documentation activities." [15]
Attribute	"…a specific characteristic of the object: what is being measured. Information resource speed, blood pressure, the correct diagnosis (of a clinical case), the number of new

	patient admissions per day, the number of kilobases (in a strand of DNA), and computer literacy are examples of pertinent attributes within biomedical informatics.” [14]
Data Standard	“…uniform use of common terms and common methods for sharing data.” [4]
Domain characteristic	A particular attribute selected due to the specific characteristics important for a particular system evaluation, for example characteristics may be more important for certain diseases or public health functions
eHealth	“the transfer of health resources and health care by electronic means.” Using information technology and e-commerce for health, public health and health services. [16]
Electronic Health Record (EHR)	An EHR is a digital representation of a patient’s traditional paper chart and all associated data. EHRs contain a patient’s medical history and are used to automate and streamline healthcare provider workflow. [17]
Evaluation	“… the systematic application of social science research procedures to judge and improve the way information resources are designed and implemented” [18]
Folksonomy	A folksonomy is a classification method where content is organized collaboratively by users creating and changing tags to annotate objects and content over time [19]
Information System	“… a discrete set of IT, data, and related resources, such as personnel, hardware, software, and associated information technology services organized for the collection, processing,

	maintenance, use, sharing, dissemination or disposition of information in accordance with defined procedures, whether automated or manual." [15]
Information Technology	"… any equipment or interconnected system or subsystem of equipment that is used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission or reception of data or information by an executive agency." [15]
JavaScript Object Notation (JSON)	"…a lightweight data-interchange format. It is easy for humans to read and write. It is easy for machines to parse and generate." [20] JSON is a rapidly accepted method for exchanging data in a machine-readable format that can be reused across the diverse and growing set of devices, applications, services and systems.
Operations	"…day-to-day management of an asset in the production environment and include activities to operate data centers, help desks, data centers, telecommunication centers, and end user support services... Operational costs include the expenses associated with an IT asset that is in the production environment to sustain an IT asset at the current capability and performance levels including Federal and contracted labor costs; and costs for the disposal of an asset." [15]
Public Health Informatics	"…the systematic application of information and computer science and technology to public health practice, research, and learning." [4]

Public Health Surveillance	"…ongoing, systematic collection, analysis, interpretation, and dissemination of data about a health-related event for use in public health action to reduce morbidity and mortality and to improve health" [21]
Stakeholder	"…those who are or will be affected by a program, activity, or resource." [15]
Surveillance	"the ongoing systematic collection, analysis, and interpretation of health-related data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know." [22]
Surveillance System	A surveillance system is an organized infrastructure that enables the ongoing systematic collection, management, analysis, and interpretation of health-related data, followed by their dissemination to those who need to know so they may: Monitor populations to detect unusual instances or patterns of disease, toxic exposure, or injury; Act to prevent or control these threats; Intervene to promote and improve health. The term surveillance system applies to both electronic and paper-based systems. [23]
Systematic Review	"a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review" [24]

Tool	A tool is an application that supports surveillance by enabling a very specific task (e.g., message transport, data transformation, communications, identity management). Tools differ from systems mainly in size, complexity, and the number of functions they support. A system can be comprised of multiple tools to meet a function or business need. In the context of the National Biosurveillance Registry for Human Health, a tool is an application that provides targeted functionality that can be used independently or by a system. The Public Health Information Network Messaging System (PHIN MS) is an example of a tool [23].

Table 1 Definition of terms used within thesis

Chapter 2: Literature review

This research builds on the body of literature for public health system evaluation, non-health technology evaluation. This literature review is organized into sections depending on what material is available for:

- Public health system evaluation frameworks
- Health system evaluation frameworks
- Systematic review approaches
- General technology assessment frameworks

The available literature provides a perspective on what attributes are presented as the minimum necessary set of conditions that should be included within the evaluation of an information system. These evaluation frameworks were frequently cited within the evaluation publications included in this research's systematic evaluation, but were expanded upon by the authors of numerous system evaluation publications.

While public health evaluation frameworks provide clear alignment to public health priorities, other evaluation frameworks from healthcare and global health provide a useful perspective on what attributes and measures are commonly used for evaluating the impact of eHealth systems and interventions.

In order to develop and refine the procedures of the systematic review it was useful to identify different methods available for planning and conducting systematic reviews. An appropriate design of systematic review procedures was important to be able to accurately determine what attributes are commonly and most frequently used as part of public health information system evaluations.

Finally, including general IT analysis and assessment literature, unassociated with health altogether, was useful in identifying how technology is commonly evaluated for maturity and applicability within organizations. The level of maturity of a particular technology is an important factor for organizations with varying levels of informatics expertise to be able to adopt and support new technology.

Public health information system evaluation frameworks

CDC has sponsored the creation of four major evaluation frameworks from 1988 through 2011 [1, 21, 25, 26]. These evaluation frameworks form a strong basis for determining what attributes are intended by expert public health practitioners and even informaticians. While these attributes are intended for assessing a complete information system rather than individual components of these systems, they provide a strong basis and understanding of what is important from a public health perspective.

Dr. Klaucke and the CDC Surveillance Coordination Group present a set of best practices and recommendations for how public health surveillance systems should be evaluated. The earliest framework is not specific to information systems, but presents a method for evaluating the system independent of its informatics components. Partially this is an artifact of its time as information systems were quite nascent in 1988, but this framework also presents the priority of focusing on the public health impact of the system independent of technology. This early framework's goal is to finally present best practice guidance on how public health programs can assess and evaluate the effectiveness of their surveillance. This framework, like other public health frameworks are specific to surveillance systems and include attributes that are very useful to surveillance and outbreak detection such as timeliness, that are less relevant to non-surveillance systems such as surveys, laboratory systems and public health registries. Later frameworks like the 2011 framework are adapted to the technology and informatics aspects of systems independence from their need to provide surveillance functions.

Each framework presents a process or set of tasks for conducting evaluations in such a structured way as to be able to be reproduced by secondary evaluations as well as the output of evaluations to be able to compare the impact of different surveillance systems. In 1988, CDC proposes a set of six tasks:

1. Public health importance – describe the system under evaluation in terms of the importance of the public health event under surveillance. This task explains the need for the system and need for the data collected and used within the system and frames the evaluation in terms that do not emphasis information technology.
2. System Description – a thorough description of the system under evaluation including the objectives, what events or diseases are under surveillance, a graphical representation of the system, and the components and subcomponents within the system. This task provides a understanding of what a system is attempting to accomplish and describes the system in multiple views and perspectives for each potential reader type of the evaluation: policy maker, public health practitioner, data provider, and potential other stakeholders and user types.
3. Usefulness – a description of the output and uses of the data produced by the system. This task assesses whether a system actually meets the need and design as described in tasks one and two.
4. Attribute-based evaluation – an assessment 7 system attributes determined to be important for surveillance systems. This set of attributes is the first time a common set of attributes is defined that together will attempt to reach objective measures of a system's quality that will allow funders to determine the impact of the system and system providers to determine how a system can be revised and improved over time.
    a. Simplicity - the simplicity of both the structure of the system and how users interact with the system. This attribute includes the directive that a system should be as simple as possible to meet its objectives but not so simple as to miss necessary requirements and functions.
    b. Flexibility – the ability of the system to adapt to changing stakeholder needs through operation of the system. Because public health conditions may change between the initial set up and deployment of a system and while it is used over

time, it is important that a system be able to adapt to new uses needed by existing stakeholders as well as meeting the uses of new stakeholder groups.

c. Acceptability – the willingness of stakeholders to participate and extract value from the system. This attribute is called out based on how users interact with and use the system versus their potential to abandon the system or use alternate, less effective surveillance means that may not meet the functionality needed by the sponsoring public health program. Later frameworks will include similar attributes such as ease of use, learning curve for adoption and user satisfaction. This attribute becomes important and called out by non-public health frameworks as a differentiating factor for how users interact with the system, also called human computer interaction. As technology adoption matured from 1988 through the 2000s, acceptability and ease of use became differentiators between similar systems that both meet functional requirements.

d. Sensitivity - the proportion of cases of a disease or condition the system is meant to detect that are detected by the system. Public health system evaluation frameworks were able to break out and include the ability to measure specific public health attributes such as sensitivity. Non-public health system evaluation frameworks included similar attributes like accuracy and validity to measure how a system was able to identify and reflect the condition under investigation.

e. Predictive Value Positive - the proportion of cases detected by the system that have the disease under surveillance. Early frameworks measured sensitivity and predictive value, positive separately to be able to measure the true positives and true negatives identified by the system.

f. Representativeness – the ability of the system to accurately reflect the detected events to the occurrence of events within the population. Early frameworks brought up the importance of data quality as a need that systems must meet, but only representativeness was first called out in 1988. In 2001, CDC would include a stand along attribute for data quality and in 2004, CDC would include data quality and its subcomponents of representativeness, validity and completeness.

   g. Timeliness – the amount of time between each step of the system. In early frameworks timeliness was focused on surveillance and the need to understand that data was more useful for enabling decisions closer to the point of occurrence. Later frameworks would describe this attribute more specifically for outbreaks.

5. Costs – describe the resources that are necessary to operate and use the system. While costs was broken out as a major component in early frameworks, successive frameworks expanded this task to include assessment of different types of costs- direct and indirect- compared to the benefit or describe value in the usefulness task evaluation. The 2011 framework greatly expanded this task to describe changes in software and hardware licensing models and how these license models affect operations and maintenance costs for how a system can be adopted.
6. Conclusions and recommendations – summarize whether the system is accomplishing its purpose and describe recommendations to improve the system based on findings. This task was included in the initial framework and is a consistent best practice in all frameworks to provide the evaluation team a task to qualitatively summarize a system's current state as well as to issue recommendations for changes necessary as well as recommendations for similar systems or program adoption of systems.

In 2001, Dr. German and others from the CDC Guidelines Working Group published a new evaluation framework that sought to establish methods for consistent evaluation to help the integration of surveillance systems, establish reusable data standards, increase the electronic exchange of health data and to facilitate the response of public health to new emerging health threats. This paper expanded on the earlier work described above in CDC's 1988 guidelines by adding additional attributes necessary for evaluation and clarifying changing needs within public health from 1988 to 2001. Specifically, the evaluation guideline was enhanced to compensate in the increased use and value of electronic surveillance systems over non-electronic systems, particularly in enhancing the timeliness and data quality attribute of completeness [27]. While the updated guidelines still focus on surveillance systems and even non-electronic surveillance systems it included new attributes that were specific to eHealth systems such as stability and reliability of how a system is able to perform in a consistent manner.

The 2001 framework includes all of the initial seven system attributes while adding in two additional attributes that were identified:

1. Data quality – the completeness and validity of the data contained within the system. Representativeness is still considered a separate attribute but is assessed in combination with new attributes of how a system's data are suitable for use by epidemiologists and other public health practitioners. When compared to other health evaluation frameworks, this attribute becomes very common to describe the differences for how a system meets its usefulness requirement as if a systems data are not dependable, then it is a challenge for whether a system is worthwhile or can be effectively used.
2. Stability – the reliability and availability of the system to be used by its stakeholders. This attribute is new in 2001 to reflect the new adoption of electronic systems and the instability that occurs when systems are not designed and maintained in a way that provides continuous uptime. This attribute also addresses what other frameworks will call sustainability or the costs associated with continuous maintenance and operation.

German's framework also has six tasks, but these six tasks have different names and particulars but still fulfill the intention of the 1988 evaluation tasks:

1. Stakeholder Engagement – involve the appropriate stakeholders of the surveillance system in the execution of the evaluation. This task replaces the earlier task of public health importance. Although the importance of a system is still paramount, German's framework focuses on the social aspects of how different stakeholder groups are engaged to define, develop and use the system. Each stakeholder's public health need is defined and mapped to an eventual system function in the following tasks.
2. System Description – describe the public health importance and need of the system, the purpose of the system and how it operates and the resources required to operate the system. This task is common through all public health evaluation frameworks and continues to make sure that the evaluators capture the intended functions of a system as compared to the actual performance that is assessed during task #4, evidence gathering.
3. Focus of Design – efficiently planning the approach and execution of the evaluation to be performed. German et al present the importance of how the evaluation is designed and was carried out. It introduces the ability of an evaluation team to introduce and explain the need for additional attributes to be measured during task #4, evidence gathering. This was an important factor in how the evaluation tool produced by this research included the ability for evaluators to customize and vary from guidance when appropriate.
4. Evidence Gathering – collect evidence of the system performance according to usefulness as well as through 9 attributes that are important to system functionality.
5. Conclusions and Recommendations – present a summary of the evaluation with any suggested changes that should be implemented within the system. This task is also common to all of the public health evaluation frameworks.
6. Lessons Learned – strategies for how the findings of the evaluation should be shared with the public health community. German introduces this task as independent from

conclusions to allow for evaluations to be generalizable to other systems, other public health programs and other evaluation teams who will be able to benefit from the findings of a particular evaluation.

In 2004, Dr. Buehler and the CDC Working Group for evaluation published a revised framework for evaluating surveillance systems through the lens of early outbreak detection. This framework was released based on the experiences of detecting potential bioterrorism events and introduced new aspects, tasks and attributes that, although intended for being important for outbreak detection, are still generalizable to other non-outbreak public health information systems.

Rather than presenting an approach focused on tasks and attributes, the Buehler framework is broken into four category sections of the evaluation: system description, outbreak detection, experience and conclusions with the expectation that any system evaluation cover all four areas.

System description is broken into three elements: system purpose, stakeholders and system operation. The purpose is important to an evaluation by setting the context for the importance of other elements of the evaluation. For example, a system intended to detect rare terrorism events, and then the priorities of the system will be different from one intended to detect routine foodborne disease outbreaks. The stakeholders of a system are important to describe the relationships between the different parties providing data, using the system directly and using the outputs and analysis of a system. Operation is meant to describe the workflow and specific actions of a system in context of how it meets its priorities.

The Buehler framework calls for the need to evaluate systems based on 9 attributes called domain characteristics. These attributes are partially common with earlier frameworks, but combine together Representativeness and Data Quality into a single attribute and introduce a new attribute called Portability. Portability is the ability of a system to be reused from a setting other than where it was originally developed. Later frameworks will include similar attributes such as generalization and customization and emphasize that it is important for systems to not only be flexible to adapt to shifting requirements but also not be solely specific to a particular program or jurisdiction's needs.

In 2011, CDC's Informatics Research and Development Unit (IRDU) published an evaluation tool specifically for public health informatics evaluation rather than specifically for surveillance systems. This tool was intended to guide public health informaticians in assessing technology tools, including but not limited to information systems, in a structured manner that allowed objective comparison of evaluation quantitative scores as determined by an evaluator or evaluation team. This framework differs in that it is the first framework intended for use by informaticians rather than by epidemiologists or public health surveillance specialists.

The tool provides a quick summary of tool evaluations including keywords for discovery, alignment to public health business processes, establishing weighting conditions to be used within the evaluation, comparison to alternatives approaches and a description of the legal and license characteristics of the tool. The tool also introduces the concept of having a graphic visualization summary of each evaluation to allow for aggregation and publishing of evaluations in a Consumer Reports style that allows reuse of the evaluation output by non-informatics decision makers.

This tool requires evaluation with 7 domain characteristics that are similar to the attributes presented in earlier public health frameworks but leaves out data quality and timeliness and adds in the attributes:

- Performance – the responsiveness and operational performance of a system. This characteristic is slightly different than Buehler's usefulness in that it directly refers to the speed of how the system responds to user interaction (i.e., user interface time between button press and system function change, time lapse between query submitted and response received). Also similar to timeliness, performance focuses on the time spent within a systems' functions such as the time between when a user presses a button and when the system completes the expected action, where timeliness functions on the time between data collection and availability. Performance is included for similar reasons to why acceptability or ease of use are included.

- Ease of installation – how a tool is installed and integrated into a public health process or system. Earlier frameworks include this as a factor of costs or acceptability, but this 2011 framework has a separate attribute to call how easy it is for a system to be quickly installed and integrated into an organization's portfolio of available systems or tools.

Earlier frameworks include an attribute for usefulness to describe how a system accomplishes its purpose, but the 2011 framework calls this attribute "domain functionality" and combines the tasks of describing the requirements of a system as well as how the technology meets these requirements. Domain functionality is a customized description of the specific functionality provided by a tool according to its aspect of public health or disease domain. This area varies depending on the intended use of the tool and its alignment to the public health business processes. This is similar in concept to Buehler's description of the outbreak detection specific needs for evaluating outbreak systems.

This framework includes quantitative elements in the form of an evaluator scoring each attribute on a scale of 1-10 and then allowing evaluators to weight each attribute according to their organizations needs to produce an overall score between 1-100. While this numeric score presents a quick summary of a technology's overall grade, it presents challenges in the amount of time necessary to develop and review a scoring and weighting system. This experience factored into this research's tool development in that rather than having evaluators develop a specific numeric score, this research uses a non-interval determination of positive, neutral or negative for each attribute. Figure 1 below shows an example scoring visualization that collects together an evaluations score by each attribute weighted by the important assigned during the evaluation design. Earlier frameworks do not include quantitative measures so while diagrams and images are included in evaluations, this framework explicitly calls out and instructs evaluations to include visualization of the evaluation's findings in an easy to understand manner.

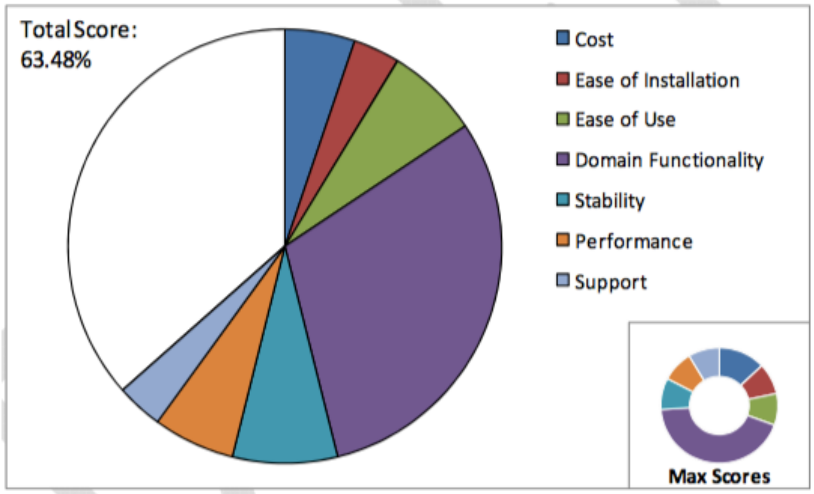


Figure 1 Example visualization of technology scores by attribute and maximum scores available.

These four evaluation frameworks provide a strong background of what a base set of attributes should be for assessing future technology, systems and other tools. The challenge in evaluating non-public health technology is in trying to determine how attributes relevant to public health can be generalized to test and assess technologies that do not address public health needs like sensitivity and predictive value, positive.

One element that was important in viewing how these frameworks determined how a system was useful or met public health needs was how systems fit into public health practices, sometimes called business processes or public health work flows. A search of the grey literature for a reference set of defined public health business processes revealed the Public Health Informatics Institute's Common Ground Project [28]. The Common Ground Project was developed with funding from the Robert Wood Johnson Foundation and presents the results of a collaborative process with national, state and local public health for documenting and defining business processes within public relevant for inclusion within technology and system evaluations. Emory's Public Health Informatics coursework includes training in using the business process definition and documentation processes for creating novel activities, but this resource is used to provide a suggested reference for existing public health practices that evaluators can use to signal what parts of public health have high potential to be improved by using a technology.

Since many technologies and tools are not specifically designed for use within public health, the Common Ground method presents a means for aligning tools for use within public health and evaluating based on the characteristics of those specific public health business processes. Common Ground defines a business process as the way that a public health organization conducts its activities to achieve specific public health goals and objectives. The framework describes and captures business processes used within public health with the following characteristics: name, goal, objective, business rule, trigger, task set, input, output and outcome.

While Common Ground is a framework for public health to use to describe its processes, the community around Common Ground has worked to describe a set of business processes that serve as an initial baseline for use in aligning evaluations to public health:

- Conduct Exercise To Evaluate Organizational Response Capacity
- Conduct Syndromic Surveillance
- Conduct Notifiable Disease Surveillance
- Conduct Active Surveillance
- Conduct Public Health Investigation
- Initiate Alerts
- Develop And Report Situational Information
- Manage Resources
- Develop And Initiate Risk Communication
- Administer Medical Countermeasures (MCMS)
- Data Collection

- Data Management
- Process, Store, And Analyze Data
- Conduct Epidemiological Research
- Community Health Assessment
- Develop Strategic Plan
- Identify And Deploy Health Guidelines
- Deliver Programs And Services
- Develop Public Health Intervention
- Link Individuals/Populations To Programs/Services
- Develop And Implement Program Evaluation

This is not an exhaustive list of all business processes and activities used within public health but serves as a valuable resource for informaticians when trying to determine how tools under evaluation can fit into public health practice. This set is used as an appendix within the research's evaluation tool to allow for evaluations to consistently mark where within public health practices technology can be used.

Health system information evaluation frameworks

While the public health evaluation frameworks were valuable to understand how public health agencies intend for systems to be assessed, it was important to find additional frameworks for evaluation to help generalize attributes for application to non-public health and non-health technology. Evaluations within the health literature frequently referenced and followed Dr. Aqil et al's Performance of Routine Information System Management (PRISM) framework [7] and Dr. Sajwani et al's PANACeA framework [11].

The PRISM framework was developed to improve the evaluation of routine health information systems (RHIS) to improve the performance of health systems within low resource environments and developing countries. A difference between the PRISM framework and the early public health system evaluation frameworks is that PRISM is developed specifically for eHealth systems. While not developed with the particular lens of public health, the techniques for systematic design and evaluation of health systems are useful for evaluation of new technology for use within public health. The PRISM framework provides four tools (performance diagnostic tool, office/facility checklist, organizational and behavioral assessment tool, and the management assessment tool) that follow a logic model of inputs, processes, outputs, outcomes and impact. While PRISM does not call out attributes, Table 2 demonstrates how each tool collects specific information items collected that are the same or similar to the set of attributes called out within the public health specific frameworks.

PRISM Tool	Unit of Analysis	Information Collected
RHIS performance diagnostic tool	RHIS performance	Data quality
		Information use
	Processes	System processes
	Promotion of culture of information	System communication
	Supervision quality	
	Technical determinants	Simplicity/Complexity
RHIS overview, office/facility checklist	RHIS overview	System mapping
		Data collection and transmission
		Information flow chart
	Office/facility checklist	Availability of equipment and data
		Availability of human resources
RHIS organizational and behavioral assessment tool (OBAT)	Behavioral	Self-efficacy for RHIS tasks
		Motivation
		Problem-solving skills
	Promotion of a culture of information	Data quality
		Empowerment/accountability
	Reward	
RHIS management assessment tool (MAT)	RHIS management functions	Governance
		Planning
		Training
		Finance

Table 2 PRISM Tools mapped to units of analysis mapped to information collected.

The PRISM framework presented a clear logic model (Figure 2) for how the different evaluation sub tools were to be used, by whom and to what purpose to assess the overall quality and performance of eHealth systems. This logic model is useful for demonstrating how the evaluation breaks down an information system to the health inputs and determinants, processes, outputs, outcomes and impact and connects them to the evaluation tasks and processes. This is a graphical representation of what public health frameworks call a system's usefulness.

PRISM uses many similar attributes as the earlier frameworks from CDC and Sosin, but groups attributes into tools, unit of analysis and then information collected. PRISM is the first framework, chronologically to put a large focus on the organizational, behavioral and social aspects of a system and how they are important for how a system is able to be effective at meeting its purpose. Organizational assessment was a common attribute addressed in this research's systematic review as the maturity and capability of organizations and the cultural aspects of the users working with a system or technology are important to whether a technology is able to create the necessary impact.

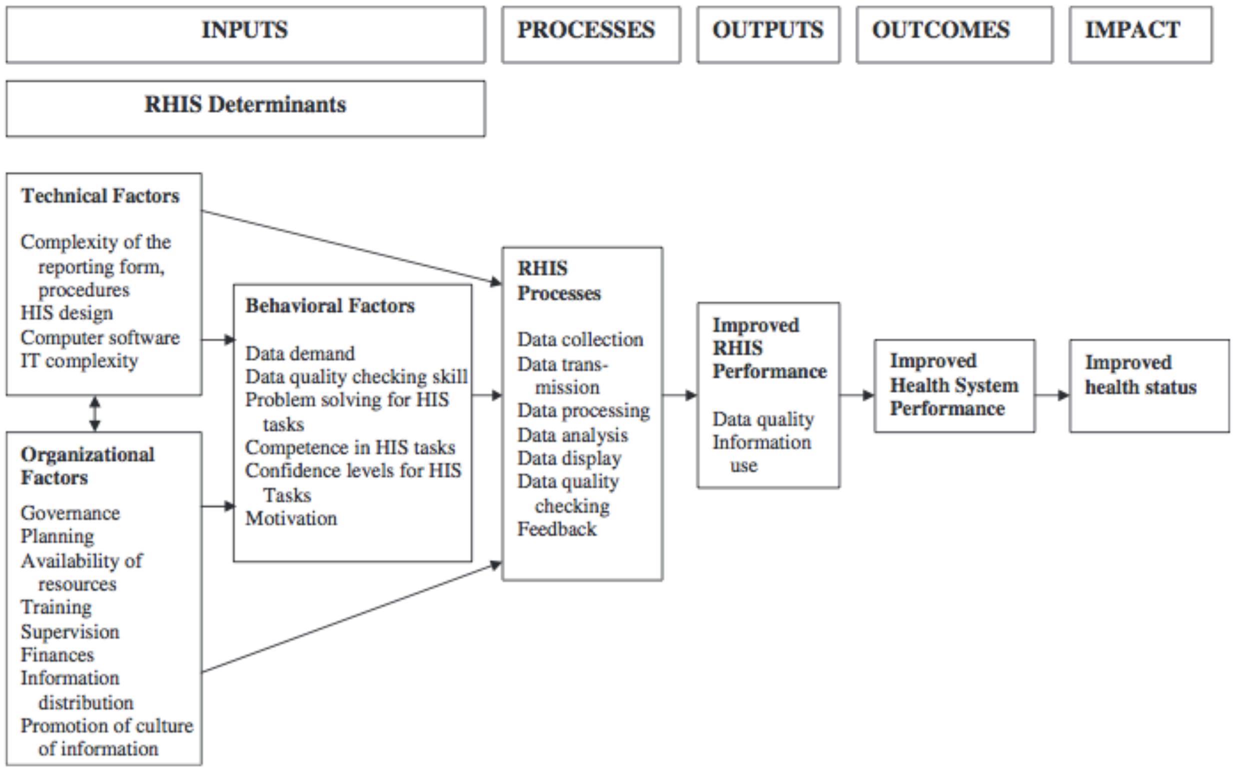


Figure 2 PRISM framework logic model

In addition to the PRISM framework, evaluations reviewed during this research pointed to another health evaluation framework that was not developed for public health systems still contained useful lessons in developing a technology evaluation tool: the Pan-Asian Collaboration for Evidence-based eHealth Adoption and Application (PANACeA) evaluation method [11]. PANACeA was developed to meet the specific needs of low resource countries and is applied within global health settings for improving programs and services within low resource environment. This framework developed an evaluation tool focusing on key evaluation questions (KEQ) rather than evaluation attributes. KEQs were open ended in order to stimulate the participating systems into sharing their opinions structured around three main categories: Collaboration and Teamwork, Capacity Building, and Knowledge Management. This process of stakeholder evaluation follows the subjectivist evaluation techniques of focus groups and both formal and informal interviews [4].

Twenty-three KEQs were developed to serve as an evaluation guide that was performed by trained evaluators interviewing users and administrators of systems under evaluation. The KEQs were organized under the main three categories and a set of sub-categories to group KEQs together. Table 3 describes the organization of the KEQs into a hierarchy:

Category	Subcategory	Sub-subcategory
Collaboration & Teamwork (14)	Network Approach (6)	Understanding of network approach
		Strengths of PANACeA network
		Weaknesses of PANACeA network and changes for future
		Challenges of PANACeA network and changes for future
		Value of network approach
		Transparency and accountability in conducting research
	Communication (6)	General tools and modes of communication
		Communication within the projects
		Communication between different projects
		Network's help for participation and capacity building of different sexes
		Network's help for participation of people with different experiences and perspectives
		Factors fostering effective communication
	Participation (2)	Network members functioning together
		Network's role in fostering partnership
Capacity Building (3)	Capacity building in eHealth and eHealth Research (3)	Capacity building activities for eHealth and eHealth research
		Outputs and outcomes of capacity building initiatives
		Suggestions for capacity building in eHealth research
Knowledge Management (6)	Dissemination (4)	Network's support for dissemination
		Dissemination done by members
		Member's access to external stakeholders via network
		Use of PANACeA findings by externals
	Policy Impact (2)	Policy impact brought via network
		Suggestions for activities for dissemination and policy change

Table 3 PANACeA Key Evaluation Questions Category Hierarchy

This evaluation framework was also developed to meet specific eHealth needs and so serves as a useful example of what attributes are specific for evaluating technology rather than as complete business processes or work flows such as described by the public health evaluation frameworks.

While PRISM had heavy attributes focused on organization and social, PANACeA expands this focus on organizational fit with the policy stakeholder interaction through collaboration. PANACeA places importance in identifying the underlying infrastructure used by or provided by the system under evaluation.

Systematic review frameworks

Identifying existing public health and health frameworks gave an understanding of what attributes were designed to be included, but this research needed to confirm what attributes are used in common practice as well as develop a method to harmonize attributes from being specific for use in assessing health technology to more generalized attributes that can test technology for usefulness within public health. Coursework at Emory University identified the Cochrane Handbook [29] for conducting systematic review and references within other reviewed literature identified the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISM) statement [24] for identifying elements that should be included within systematic reviews.

The Cochrane Collaboration is an international organization focused on improving the ability of decision makers to use high quality systematic reviews about healthcare and health policy. The Cochrane Collaboration develops methods for conducting systematic reviews and collects these methods into handbooks to guide reviewers in conducting systematic reviews with the aim of minimizing bias.

The handbook defines a systematic review as an attempt to collate all existing empirical evidence that fits reviewer defined eligibility criteria in order to answer specific research questions. The handbook presents five key characteristics for reducing bias through systematic review:

1. Clearly stated set of objectives with pre-defined eligibility criteria for studies
2. Explicit, reproducible methodology
3. Systematic search that attempts to identify all studies that meet eligibility studies
4. Assessment of the validity of findings of all matching studies
5. Systematic presentation of the findings of identified and admitted studies

This research does not use the fourth characteristic as the studies identified are used to collect the frequency of attributes used in evaluation rather than assess the findings of each evaluation.

PRISMA was developed for healthcare, not public health, and identifies four major concepts to be addressed by health systematic reviews:

1. Systematic reviews are an iterative process
2. Conducting research and reporting on research are distinct concepts
3. A thorough assessment of the risk bias in review requires both an assessment on both the study-level and outcome-level
4. Accurately describing the different types of reporting biases

The PRISMA statement presents a 27-item checklist of elements that are useful to include in a systematic review as well as four-phase process of identification, screening, eligibility and inclusion for conducting systematic reviews. Both the checklist and process flow were useful in conducting the research within this thesis to reducing bias in identifying attributes that are useful for evaluating tools and technologies. This four-phase process was used to design and carry out the method of this research.

While this thesis itself is not a systematic review, it uses the elements of the systematic review as an input to developing an evaluation tool. The 27-item checklist includes the elements of:

- Title
- Abstract with structured summary
- Introduction
    - Rationale
    - Objectives
- Methods

    - Protocol and registration
    - Eligibility criteria
    - Information sources
    - Search
    - Study selection
    - Data collection process
    - Data items
    - Risk of bias of individual studies
    - Summary measures
    - Synthesis of results
    - Risk of bias across studies
    - Additional analyses
- Results
    - Study selection
    - Study characteristics
    - Risk of bias within studies
    - Results of individual studies
    - Synthesis of results
    - Risk of bias across studies
    - Additional analysis
- Discussion
    - Summary of evidence
    - Limitations
    - Conclusions
- Funding

The literature available on systematic reviews was integral to designing the systematic review portion of this research as well as in documenting and addressing selection bias and developing methods for identifying reporting biases for publications selected for inclusion within the systematic review.

General technology assessment frameworks

The final element of this research's literature review was to identify other research that addresses the non-health altogether concept of technology maturity and adoption risk. Gartner Inc., is an information technology analyst firm that provides search analysis to clients within various industries, including healthcare and public health. Gartner publishes a graphical tool called the Gartner Hype Cycle [30] is an information technology maturity assessment tool. The hype cycle describes where a technology is within a life cycle of early adoption through to productivity and eventual retirement. The research is used by organizations looking to learn about the promise or a new or emerging technology within the context of their own organization and ability to accept risk.

The hype cycle collects technology onto a spectrum that falls into five phases of technology life cycle described by Gartner as:

- Technology Trigger – a very early technology only recently introduced. These technologies are early proofs of concept and frequently lack any usable product.
- Peak of Inflated Expectations – technology begins to be adapted and tested by arly stage companies that include both successes and failures
- Trough of Disillusionment – initial projects begin to complete, sometimes unsuccessfully. Technologies only progress beyond this stage if they improve and mature.
- Slope of Enlightenment – companies begin wide adoption of a technology with second and third generation projects run through completion.
- Plateau of Productivity – mainstream adoption of a technology.

While this assessment tool is not developed specifically for public health, it is useful for determining where a new technology exists within its life cycle. Evaluators then need to take into account their organization's needs and culture in how much risk is appropriate for integrating and using new technology.

Summary of current problem

While the literature exists within health literature for guiding the evaluation of public health information systems and surveillance systems, there is a gap for how to assess individual technology, systems and tools from outside of health for impact within public health. Techniques for systematic review are useful for reviewing the current state of public health related literature to harmonize attributes used for assessing systems, developing a hierarchy of attributes and using them to create a novel tool for use in assessing tool for potential impact to public health.

Chapter 3: Methods

Introduction

The research carried out by this thesis takes place in three stages, a systematic review of existing public health literature for evaluation studies to identify common attributes, a harmonization of attributes by similarity of concept, and the development of a guided tool that uses commonly used attributes.

Population and sample

This systematic review is conducted on the body of literature as indexed by the National Library of Medicine (NLM)'s PubMed service [31]. MEDLINE, also provided by NLM, was considered but Pubmed was selected due to the larger collection of citations and publications of in process and ahead of print articles for greater timeliness. Pubmed Central was also considered but Pubmed was selected due to the greater selection within Emory's library resources and CDC library resources.

The review is performed solely by the author based on the controls of the Emory academic honesty policy. This bias is described in more detail in the limitations.

Research design

This research design is separated into three stages as described below in Figure 3: systematic review of public health informatics system evaluations, harmonization of evaluation attributes, and new evaluation tool development.

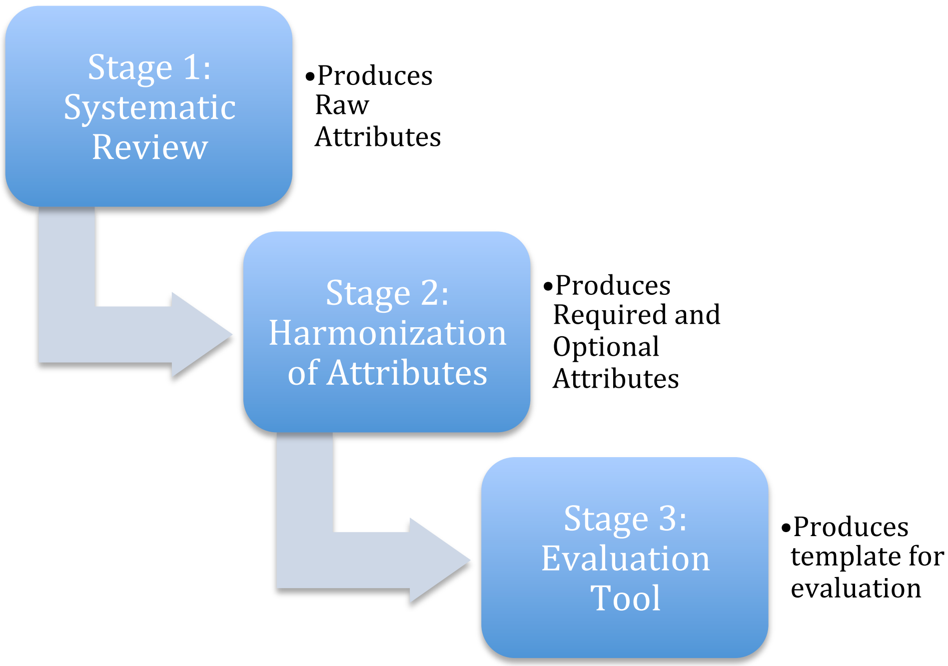


Figure 3 - Research Stages with Incremental Output

Stage 1: Systematic review

The inclusion criteria for the review considered the following types of documents: peer-reviewed articles conducting assessment or evaluation of one or more information systems, peer-reviewed articles presenting a framework for evaluation of information systems and reports from global health agencies.

The reviewer extracted attributes used as a significant element of the evaluation. Attributes will be defined using a combination of the reviewed literature and the reviewer's subject matter expertise. Data extraction will differentiate attributes mentioned directly (marked with "X") or attributes that apply to the evaluation based on context and meaning, but not directly mentioned (marked with "I"). For example, an evaluation that does not mention "accuracy" explicitly, but does mention how values within the system are compared against another system that has similar values still uses the concept of accuracy as part of the evaluation. The reviewer developed a harmonized glossary of attribute definitions that were used as part of the developed evaluation tool in stage 2 of this thesis.

The search strategy was designed to access published and not yet published, but approved, documents using the following steps:

1. Pubmed search will be restricted to English-language journal articles using the following search queries:
    a. "public health" AND ("system" OR "tool" OR "framework") AND ("evaluation" OR “evaluating” OR "assessment" OR “assessing”) AND ("informatics" OR “information technology” OR “IT”) [456 results]
    b. "public health informatics" AND (evaluation OR assessment) AND (system or tool or framework) [182 results]
2. Bibliographies from eligible documents will be reviewed and with additional articles identified based on title and author.
3. Public health agency websites for the US Centers for Disease Control and Prevention, World Health Organization, Gates Foundation will be searched for relevant documents based on title and document body text that reference peer reviewed documents.

In order to be included in the analysis, each publication must be valid. Validity was determined if a publication:

1. Has the basic characteristics expected in peer reviewed literature such as possessing a well-defined purpose and research methods; performing sound data collection and analysis methods; and presenting clear findings and conclusion [32].
2. Only includes evaluation of a system, software tool, or technology.
3. Focuses on information systems. Literature that focuses on non-informatics aspects of a system will not be included.
4. Is not a systematic review or meta-analysis. Literature that is itself is a systematic review will not be included to prevent duplicate counting of attributes, but review bibliographies will be reviewed for inclusion.

If a publication was determined to be valid, it was included in the data collection tool and its attributes and measures were added to a matrix of publications to attributes described below. If a publication was not valid, it was noted but not included for analysis.

Data collection took place by the reviewer extracting all attributes used in the evaluation of the identified system or systems within the document. The first phase of data collection was in identification of documents from Pubmed and bibliographies. Any duplicate records were removed from the review set. Remaining titles and abstracts were scanned and any ineligible documents were removed. Only documents that described evaluation frameworks or directly evaluated a system were included. Remaining documents had full text assessed and any ineligible documents were removed.

Data was synthesized by grouping attributes into related hierarchies of concepts based on definition within document and reviewer's informatics experience.

Stage 2: Harmonization of evaluation attributes

The raw matrix of attributes to publications was reviewed to consolidate similar and related terms using the reviewer's expertise in public health informatics. For example the concepts of sensitivity and accuracy were grouped together as accuracy is a broader concept outside of public health, but still applicable to tools being able to achieve accurate results based on user expected behavior.

Stage 3: Tool development project

Using the synthesized data from the harmonized attributes, the author created a template document that serves as a new evaluation tool that includes a set of common attributes relevant to public health. The author used informatics subject matter expertise to develop weighting schemes and visualization techniques for how the tool can represent any quantitative conclusions from the evaluation. The goal of the project was to develop a Microsoft Word template tool that includes instructions for completion with a full level of detail and an abbreviated level when limited resources are available for evaluation.

Procedures

These procedures are separated into three stages: systematic review of public health informatics system evaluations, harmonization of evaluation attributes, and new evaluation tool development.

Stage 1: Systematic review

The author reviewed publications from the public health literature using four stages of assessment: identification, screening, eligibility and inclusion. Figure 4 describes the counts of publications identified at each of these four stages, how many records were excluded at each stage and how many publications met all criteria and were included in the review [33].

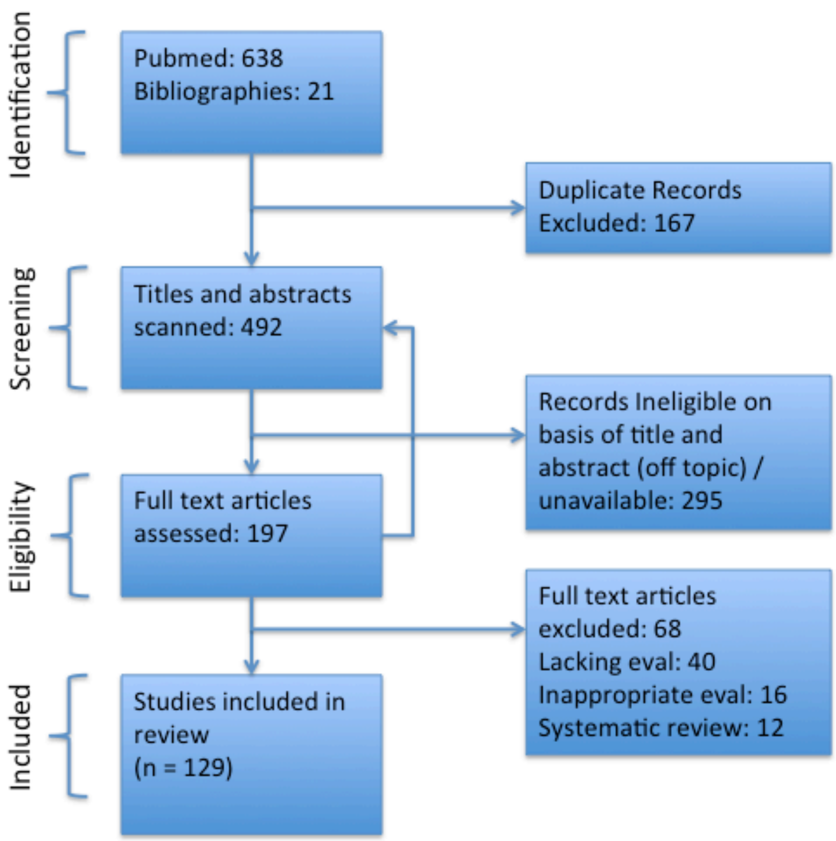


Figure 4 Selection process of studies on public health evaluation from the peer-reviewed literature.

Identification

The first phase identified potential documents for review by executing the Pubmed queries defined in the research design and used UNIX commands to filter and remove duplicate documents.

Since documents may be exist in multiple Pubmed queries, it is important to establish the true number of documents for review by performing de-duplication procedures. The steps followed are described below:

1. The results of query#1 and query#2 are downloaded comma separated value (CSV) files pubmed-query1.csv (466 lines) and pubmed-query2.csv (186 lines) from pubmed.com.
2. Both files are combined together into pubmed-combined.csv (652 lines) using the UNIX command "`cat pubmed-query1.csv pubmed-query2.csv > pubmed-combined.csv`"
3. The contents of this file is sorted into pubmed-sorted.csv (652 lines) using the UNIX command "`sort pubmed-combined.csv > pubmed-sorted.csv`"
4. The contents of this file has all duplicate entries removed so only unique documents exist into pubmed-uniq.csv (472 lines) using the UNIX command "`uniq pubmed-sorted.csv pubmed-uniq.csv`" Note: this file includes a header line that does not represent a document, so the actual count of unique documents requiring screening is 471.

Screening

Each title and abstract was reviewed and any records that did not contain evaluations or assessments or did not address informatics aspects or did not pertain to a system, tool or technology were marked as ineligible and excluded from the review.

Eligibility

Remaining records were assessed for eligibility. Eligible articles must be peer reviewed; must contain an evaluation or assessment or a system, tool or technology; must conform to

Walliman's quality requirements for research; must be within the past 20 years; and must be in English. Any records that are themselves systematic reviews or meta-analyses were excluded so as to not duplicate analysis from individual reviews. All bibliographies were reviewed and new articles were screened for eligibility and inclusion.

Inclusion

Finally, all remaining articles had evaluation attributes extracted for analysis. The reviewer extracted data from included documents using a tabular extraction form. The reviewer extracted each attribute contained within an included document. Attributes were compared to the collected set of previously extracted attributes. If an attribute did not exist in the set, it was either added as a top-level hierarchy item or added within a hierarchy based on the definition of the attribute within the included document.

As the review was carried out, each matching document was reviewed for what attributes the authors included. A matrix was developed using spreadsheet software that included the individual document and each attribute marked with either direct inclusion "X", or an imputed inclusion "I" based on the reviewer's interpretation. As the reviewer reviewed multiple existing studies and papers, each overlapping and common attribute, measure and approach was recorded. Common attributes and measures (e.g., sustainability, availability, scalability, etc.) were collected together using informatics subject matter expertise.

Similar attributes were combined together for harmonization based on the reviewer's subject matter expertise. For example, accuracy serves a similar purpose in evaluation as sensitivity and predictive value positive so for purposes of the creation of a new evaluation tool in phase 2, they can serve as a single attribute with common goal.

Frequency analysis was performed using Excel pivot tables to identify commonly used attributes. Attributes in the top quartile of frequency were included within the stage 2 tool. Attributes in the second quartile of frequency were optionally included based on the author's subject matter expertise. Attributes in the lower half were not included as mandatory attributes in the stage 2 tool, but were included in a glossary for reference by potential users.

Stage 2: Harmonization of evaluation attributes

Although different evaluation studies called attributes by different names, it was important for the template tool to present a harmonized set of attributes where different evaluation studies use different terms to represent the same concept.

This stage collected definitions from all attributes and then reviewed definitions for similarity. Common terms were merged into a consolidated concept. For each group of attribute concepts merged together, the attribute matrix was updated with a value of “M” signifying that although a document does not include reference to the consolidated attribute, it is counted due to the merging of concepts that are referenced within the document. Frequency counts were updated to reflect the applicability of the new attribute to papers that used the pre-harmonized attributes and new quartiles were then determined based on the revised frequencies for each harmonized attribute.

Stage 3: Tool development project

Using the output of Stage 2, the author collected together common attributes and organized them according to theme. Any attribute that was in the top quartile of frequency was be included in the tool, attributes in the second quartile of frequency were optionally included based on overall fit within the tool and attributes in the bottom half of frequency were not included as attributes in the tool, but were included in an appendix for optional inclusion based on the evaluation team’s judgment.

The tool includes visualization techniques for the attributes quality from the collection of literature reviewed in Stage 1 and select techniques that are commonly used within public health evaluation. The visualization technique was designed to provide a summary of the results from each evaluation that can be used as an initial screen or filter to quickly narrow down what results should be investigated further.

Instruments

All data was directly entered by the reviewer in development of this thesis based on review of literature through Pubmed. Literature included or eliminated at each phase was tracked using the Google Docs Spreadsheet web service in combination with Microsoft Excel spreadsheet software.

Plans for data analysis

Analysis was performed to identify common attribute across evaluations by using analysis functions in the two spreadsheet programs to perform frequency counts and stratification using pivot tables.

Attributes were initially sorted by frequency within the included studies. After harmonization of attributes, then frequency analysis was performed again to identify attributes used most frequently (top quartile), frequently (2^{nd} quartile) and in niche situations (bottom half).

Limitations and delimitations

In many cases, the purpose of the reviewed included documents was not to share the process of their evaluation, but the system, outcome and/or recommendations. So publication bias is in play that there are likely many other attributes used for evaluation that were not explicitly mentioned in the literature.

In limited situations, some articles (n=15) that seemed to fit the selection rules were unavailable to the reviewer. Although listed in PubMed, the publication was unavailable through Emory's Libraries and Repositories and was also not available through the CDC Library's journal collection and journal access system.

This review did not correspond with each included document's author for clarification due to the resources that would be necessary on both the reviewer and the evaluation author. A single reviewer, this author, conducted the systematic review. This presents a risk of assessment bias [14] from relying heavily on the judgment of the single reviewer. Including an additional 1-2 reviewers to perform the same procedures and reconcile differences would lead to a higher quality matrix of attribute and attribute hierarchy. Using multiple reviewers was outside the scope of this project.

Chapter 4: Results

Introduction

The results of this thesis are separated into three stages: systematic review, harmonization of attributes and development of a new evaluation tool.

Findings

Stage 1: Systematic review results

The review resulted in the review and extraction of 129 evaluations that described the use of 32 different attributes. At first, a data quality review was performed to review each paper to validate that each of the attributes was either directly references (marked with "X") or implicitly references (marked with "I"). Figure 5 shows a subset of the 129 publications as stored in matrix form. While both "X" and "I" were used for determining frequency of attributes within papers reviewed, I is used within the second quartile where the judgment of the reviewer is used to determine what attributes will included or excluded from the tool.

Paper/attribute	Year	Timeliness	Validity	Data Quality	Representativeness	Completeness	Usefulness/Workflow/Process	Flexibility	Portability	Stability/Reliability	Costs	Ease of installation	Ease of use/Training	Performance/Efficiency	Description/Documentation	Simplicity	Acceptability/User Satisfaction	Sensitivity	Predictive Value Positive	User Centered Design	Data Management/Interoperability	Data Dissemination	Human Factors/HCI/UI	Organizational & Social	Standardization	Accuracy	Architecture/T	Sustainab	Sup	
Kotze	2010			X			X	X			X	X									X			X						
Ashar	2009	X								X		X	X	X		I											X		X	
Mavimbe	2005		X	X																	X		I	X					X	
Sorensen	1996		X			X					X														X	X				
Eisenstein	2005										X							X												
Aqil	2009	X		X		X	X				X	X	X	X	X	I					X	X	X	X		X	X		X	
Kawamoto	2005						X			X				X									X		X		X		X	
Wuhib	2002	X			X		X	X			X				X	X	X	X	X											
Teutsch	1995	X	X	X							X	X					X	I	I		X	X			X				X	X
Ruggeri	2013		I				X						X	I			X													
Sedig	2012							X												X	X		X							X
Siegrist	2004	X					X											X	I											
Collier	2008		X											X			X	I												
Bradley	2005	X	X	X	X								X								X			X			X			X
Gastounioti	2014						X						X	X			X						X				X			
Wicht	2013		X											X													X		X	
Greenko	2003														X			X	X								X			X
Lober	2002	X		I	X					X	X				X						X	X	X		X	X	X			X
Shegog	2006						X						X		X		I									X				X
Jandee	2014	X	X			X	X			X			X		X		X										X			
Seebregts	2009			X			X			X	X		X				X						X				X			X
Quinn	2003	X		X								X					X									X				
Huang	2003			X						X			X	X													X			
Bolt	2013	X																I								X				
Smith	2007	X			X																X						X			
Lewis	2002	X		X											X			X	X								X			X
Strassburg	2002						X	X			X		X				X				X		X	X			X			

Figure 5 Subset of raw Attribute Matrix showed for illustration Purposes

Table 4 shows the frequency of the occurrence of each attribute broken out into four quartiles of eight attributes each.

Quartile 1 Attributes	Frequency	Quartile 3 Attributes	Frequency
Usefulness	67	Completeness	23
Architecture and Type of System	57	Validity	22
Timeliness	46	Flexibility	22
Costs	46	Stability and Reliability	22
Data Management and Interoperability	46	Data Dissemination	22
Data Analysis and Data Visualization	46	Standardization	22
Ease of use	43	Representativeness	20
Sensitivity	40	Supportability and Compatibility	20
Quartile 2 Attributes	**Frequency**	**Quartile 4 Attributes**	**Frequency**
Data Quality	36	Security and Privacy	19
User Interface	32	Ease of installation	12
Acceptability and User Satisfaction	29	Simplicity vs. Complexity	10
Description and Documentation	25	User Centered Design	6
Predictive Value Positive	25	Generalizability and Customizability	5
Organizational and Social	26	Ethical and Legal	4
Accuracy	25	Portability	3
Performance and Efficiency	24	Sustainability	2

Table 4 Frequency of Attributes Used Within Reviewed Evaluations

Definitions of each attribute were taken from the literature review and the published evaluation papers. When published evaluations used conflicting definitions, new attributes were created.

1st Quartile of Attributes

1. Usefulness (67 matches, 52% of evaluations) – The ability of a system to meet the objectives and priorities as designed. When possible, this attribute is used to describe by the ability of a technology to meet the disease prevention actions enabled by analysis and interpretation of the system or technology data [1]. Usefulness can also be defined as the ability of the system to meet the domain characteristics or functionality specific to this system. Evaluation should assess the ability of the system to meet the necessary functionality or accomplish its purpose. This will vary greatly depending on the type of technology and the evaluator should assess this differently depending on the type of tool. In some cases the purpose is apparent (e.g., outbreak

investigation) while in other cases the evaluator may need to contact the author of the technology to gain insight.

2. Architecture and Type of System (57 matches, 44% of evaluations) – Describing the overall architecture of a technology is important for determining fit of a technology for use within a particular public health organization. This attribute is sometimes called system design or technology design and includes important characteristics like whether it uses peer-to-peer or centralized data sharing [34]. The evaluator must assess the technology in relation to their organizational context as to whether the type of system (web site, mobile application, message queue, etc.) is an appropriate fit for the architecture of other technologies that will be used within an organization.

3. Timeliness (46 matches, 36% of evaluations) – The measure of the time between initial exposure to disease agent and the ability of the user to take appropriate public health action [1]. Buehler's definition is specific for surveillance purposes, but a simplified definition is the time elapsed between when an event occurs to when a technology renders the event actionable for a user. The specific methods to measure timeliness will vary depending on the technology under evaluation but is important for comparing different technologies as to how soon a technology is useful within public health. It is important that timeliness be all inclusive to cover all aspects of timeliness that are appropriate to a technology such as onset of exposure, onset of symptoms, onset of behavior, capture of data, completion of data processing, application of analytical processing, generation of alert, initiation of investigation and initiation of public health intervention. For technologies outside of public health, some steps may not be able to be included within the specific evaluation of the timeliness attribute.

4. Costs (46 matches, 36% of evaluations) – Cost is critical in determining the overall relative value of a technology [1] and is important in the selection of whether a technology is appropriate for use within an organization. Evaluation of the cost attribute should include both direct costs such as licensing, support, hardware, software purchases, personnel and travel; as well as indirect costs incurred across the organization for adopting a technology. The rating based on this attribute should address the cost of a system in relation to its value or results from the usefulness attribute. This can include the value of the prevention as a result of the technology but will depend on the particular aspects of a technology. In the case of software technologies, this evaluation attribute also includes the licensing model whether it is open source, commercial or government produced software. The software license model is important for determining initial costs as well as ongoing costs for support and operation.

5. Data Management and Interoperability (46 matches, 36% of evaluations) – Data management represents a variety of technology functions and features focuses on how a technology works with data within its boundaries and how data are received from and sent to outside partners. This attribute is particularly common in describing how a public health system is able to store, control access, provide access, ingest and extract data to enable to the processing of data into information. Each technology may address data management in a different manner. This attribute can be synergistic with the attribute of standardization for how it enables interoperability with other technologies.

6. Data Analysis and Data Visualization (46 matches, 36% of evaluations) – Data analysis approaches are critical to the planning, creation and execution of information systems within public health [35]. While data management focuses on the structure, storage and manipulation of data; analysis and visualization focuses on the use of data to perform the necessary functions of public health. Data analysis is related to and enables other attributes like data quality (ability

to analyze the data is critical to determining data quality) and timeliness (ability to visualize the data enables swifter decision making with data).

7. Ease of Use (43 matches, 33% of evaluations) – This attribute describes the ability of users of various levels (novice and expert) to become proficient in and use a particular technology [26]. This attribute is related to the attributes of acceptability, user interface and user centered design. The fit for a technology depends on the level of training required and the cost and availability for training on the use of a technology.

8. Sensitivity (40 matches, 31% of evaluations) – Sensitivity describes the ability of a system to detect outbreaks or epidemics [25]. This attribute is specific to public health technologies in detecting the number of matches on a disease or condition, but can be represented more generally in non-public health technologies in terms of accuracy or validity. When evaluating public health specific technologies, sensitivity is critical, but when evaluating technologies from outside the public health domain, accuracy can be used as an indicator of whether a technology will have high or low sensitivity.

2nd Quartile of Attributes

9. Data Quality (36 matches, 28% of evaluations) – Represents the completeness and validity of the data stored within a system or technology [21]. Data quality is a compound attributes that in some evaluations is stand-alone but in other evaluations is broken down into sub-components such as completeness, validity, and representativeness. While this is a public health specific definition for data quality, when evaluating non-public health technologies this definition must be adapted to reflect the ability of the technology to either consume or product data that is complete and error free. In many cases, a technology may provide specific benefits over improving data quality and/or reducing the number of errors or faults within the technology.

10. User Interface (32 matches, 25% of evaluations) – This attribute evaluated how users interact with the functions provided by a technology. Although the specific elements of a user interface depend on the particulars of a technology, examples include user authentication procedures, display of information in charts and graphs and spatial representation of surveillance data [36]. In some evaluations user interface is included as an aspect of acceptability or ease of use and the determination needs to be made by the evaluator on whether to include as a single attribute or to combine together with ease of use.

11. Acceptability and User Satisfaction (29 matches, 22% of evaluations) – The willingness of users to participate and effectively use a system [25]. This attribute is sometimes included within Usefulness as it related to how the intended users of a technology are able to integrate it into practice and are satisfied with its performance and functionality.

12. Description and Documentation (25 matches, 19% of evaluations) – It is important that a system be clearly described in overall function as well as the intended purpose that the system is trying to fulfill [1]. Each evaluation needs to include a description of the technology to give cover the purpose and intent of the system. This includes the level of documentation available for the technology and will affect the usability (i.e., clarity of documentation makes technology easier to adapt) as well as the usefulness of the system.

13. Predictive Value Positive (25 matches, 19% of evaluations) – The proportion of individuals testing positive for a condition, actually having the condition [25]. This attribute is specific to public health, but is an important representation of the accuracy attribute for use in evaluation of technologies that are built for purposes outside of public health.

14. Organizational and Social (26 matches, 20% of evaluations) – The stakeholders that use and interact with a technology on every level are critical for including within an evaluation. Including stakeholders within an evaluation provides the necessary context for understanding a system as well as providing a context for the overall evaluation results [1]. This evaluation attribute describes how a technology is adapted within an organization and addresses the social fit of the technology. This can determine how a technology is compatible with other technologies within an organization or how the technology is used differently across stakeholder groups.

15. Accuracy (25 matches, 19% of evaluations) – Is the measure of how the data within a system accurately reflects the reality of data outside of a system [7]. While the sensitivity and predictive value positive attributes are specific to public health, the accuracy attribute is related but generalized to non-public health tools. This attribute represents a technology's ability to present data that accurately represents the real value.

16. Performance and Efficiency (24 matches, 19% of evaluations) – This attribute describes a technology's ability to consistently and efficiently meet the demands of the users of the technology. This attribute measures the responsiveness of a technology [26] and its ability to maintain a useful level of responsiveness under expected user activity loads.

3rd Quartile of Attributes

17. Completeness (23 matches, 18% of evaluations) – A measure of how frequently records have blank, unknown or non-reported values [1]. Completeness is sometimes included as a subcomponent of data quality, but is sometimes evaluated independently from data quality. Evaluation using this attribute is important to determine if a technology functions in a reliable, error-free manner and if it does error does it lose data or fail to retain data. This will vary depending on the type of technology but is important in describing how a technology allows the user to cope with uncertainty or compensate for situations where data needs to be recovered.

18. Validity (22 matches, 17% of evaluations) – This attribute also varies depending on the purpose of the technology under review, for an outbreak detection tool or outbreak analysis tool, validity is the ability of a system to detect an outbreak and the generalizability between systems in how they are able to detect outbreaks given similar conditions[1]. This attribute is related to the public health specific attributes of sensitivity and predictive value positive in that it relates to the technology's ability to accurately and reliably perform its function.

19. Flexibility (22 matches, 17% of evaluations) – Flexibility refers to a system or technology's ability to adapt and change as the needs of the technology's users change [1]. The evaluation of this attribute is important to determine the ability for a technology to expand and adapt to shifting organizational changes. Depending on the type of technology, this attribute will be reflected in different manners. Since technology will be used in different manners depending on its function within public health (i.e., environmental health, health policy, infectious disease, non-communicable disease, etc.) the value of a technology is greater if it can be reused in different configurations by a wide variety of users. This is particularly valuable in data intensive tools that need to adapt as data standards change over time.

20. Stability and Reliability (22 matches, 17% of evaluations) – Stability and reliability represent the ability of a system or technology to remain functional in variable conditions and for long periods of time within failure or unexpected periods of being offline [1]. While this definition is specific to surveillance systems, it is useful in the evaluation of technologies to describe how a technology is able to withstand unexpected performance conditions and whether it can consistently respond to the user without an interruption in service. This is important in evaluating how technologies will fit into an organization as gaps in stability and reliability can negatively impact other systems used within an organization.

21. Data Dissemination (22 matches, 17% of evaluations) – Systems must be able to present and share data clearly so that it can be used by decision makers and system users [35]. This attribute represents a technology's ability to accurately share information and collaborate with users of other technologies.

22. Standardization (22 matches, 17% of evaluations) – This attribute reflects the ability of a technology to generally recognized formats for system data that increases the ability for other systems to understand and use data produced by a system [35]. This attribute is important in determining the interoperability of a technology with other technologies but varies as to how it is important within a technology. Technologies that rely more on data interchange will require this attribute to be used with a higher priority.

23. Representativeness (20 matches, 16% of evaluations) – Representativeness is the ability of a system to describe the distribution of cases generalizable to a population [1]. Another attribute that is closely associated as a sub-attribute of data quality, representativeness is particularly useful in surveillance in determining whether a technology can be used or how it can be used in conjunction with other technologies or systems. This attribute is particularly focused on data technologies to determine whether the results from the technology can be generalized to other populations under study.

24. Supportability and Compatibility (20 matches, 16% of evaluations) – This attribute describes a system's operation and the complexity of a system in relation to how users and administrators maintain the system [1]. This attribute is sometimes included in the costs evaluation of a system. This attribute is important in determining the fit of a technology into an existing mix of technologies in an organization.

4th Quartile of Attributes

25. Security and Privacy (19 matches, 15% of evaluations) – This attribute is largely driven by the US Health Insurance Portability and Accountability Act (HIPAA) of 1996 that describes privacy controls that are required to protect patient health information. However, this attribute is commonly included into the Usefulness or Architecture attributes of a system rather than broken out as a separate dimension of an evaluation. An evaluator may choose to prioritize this attribute is a technology is particularly sensitive to privacy or security concerns such as when a technology operates within multiple health care institutions [34].

26. Ease of installation (12 matches, 9% of evaluations) – This attribute describes how easy it is to install and integrate a technology within an organizations other systems and platforms [26]. This attribute is related to the ability of a technology to be implemented within an organization. It is related to the supportability of a system, but where supportability refers to the resources dedicated to the ongoing operation of a technology, this attribute focuses solely on the initial resources to bring a technology into use. The evaluator may prioritize this attribute if a technology is particular focused on situations such as outbreak investigations where new technologies are required to be installed in a short time with limited resources.

27. Simplicity vs. Complexity (10 matches, 8% of evaluations) – Simplicity describes the complexity of a systems' structure as well as how easy it is for a user to operate a technology. Systems should be as simple as possible while still fulfilling their objectives [21]. The simplicity of a technology is closely related to its usability or acceptability attributes. The more complex a system is, the more difficult it is to deploy within an organization and the greater the risk that it conflicts with other technologies used. The evaluation of a system based on its complexity or simplicity will be an important factor for organizations with limited informatics expertise to support the tool and educate users on its functionality.

28. User Centered Design (6 matches, 5% of evaluations) – User Centered Design is a process for determining the needs of a system in relation to the user and how the user needs to interact with a system [37]. This attribute is related to technology acceptability in the ability of a technology to be responsive to a user's needs and expectations.

29. Generalizability and Customizability (5 matches, 4% of evaluations) – This attribute reflects a technology's ability to be used within a diverse set of situations and be easily customized or changed by the user of the technology. Complexities in generalizability can be a barrier to adoption of a particular technology [38] by increasing the costs of acquisition as well as the resources necessary for continuing operation.

30. Ethical and Legal (4 matches, 3% of evaluations) – This attribute is important for determining whether a technology is an appropriate fit based on legal and ethical concerns of an organization using the technology or the user operating the technology [39].

31. Portability (3 matches, 2% of evaluations) – Portability describes how well a system can be duplicated and made useful in another setting outside of its primary setting [1]. This attribute describes the technology's ability to be reused in diverse situations. It is related to the simplicity attribute in that technologies that are simple are more likely to be portable to additional situations and organizations. This attribute is also sometimes linked to the generalizability of a technology from one specialized situation to other situations. This attribute is important for evaluators who are concerned with the ability of a single tool to be used within multiple diverse portions of their organization.

32. Sustainability (2 matches, 2% of evaluations) – The ability of a technology to continue in operation. This sometimes takes place through a diversity of funding organizations [40], while in

other technologies represents the likelihood of a technology to be able to consistently be available in a functional manner. Although an infrequently used attribute, it can be important to an evaluator if the evaluator's organization is particularly sensitive to the technology being used in a critical role by a great many users or dependent systems.

Stage 2: Harmonization of evaluation attributes

Stage 1 identified 32 attributes used within evaluations of public health systems. Before the reviewer could develop a tool to evaluate non-public health technologies, attribute needed to be harmonized and generalized to be more useful in evaluating technologies that do not use public health vocabularies and were not designed for the specific requirements of public health. The combination and harmonization resulted in new quartiles of attributes for use in inclusion within the evaluation tool created in Stage 3.

Harmonization is important not only for evaluating routine technology, but for technology used in novel methods within public health. The adaptation of these attributes for use within public health is important to allow for assessment of technologies using an evaluator's expertise.

Attributes were reviewed for commonality and the following attributes were combined together into single attributes:

- Portability was expanded to include Generalizability and Customizability as these concepts are similar and portability more closely represents the ideal benefit from generalizability and customizability that a technology can be ported to multiple diverse situations.
- Data Quality was expanded to include Completeness and Representativeness as completeness and representativeness are frequently defined as subcomponents of data quality so the definition of data quality can represent the two subcomponents where necessary to the evaluator
- Accuracy was expanded to include Validity, Sensitivity and Predictive Value Positive as accuracy is more generalizable to non-public health tools but still represents the spirit of

assessing whether a technology is able to accurately reflect the value of the data and detect an event. Accuracy is valuable in assessing new approaches to how data is used while maintaining that the analysis performed still has accurate and useful results. This becomes more important with the expansion of Electronic Health Record (EHR) systems and the volume, variety and velocity of data that is handled by tools and technology [41].

- Acceptability was expanded to include User Centered Design, User Interface and Ease of Use. The attribute name was expanded to be called Acceptability and User Satisfaction to represent the value to a technology of including how users interact with and their ability to effectively use the technology.
- Costs was expanded to include Sustainability as the latter was an aspect of how the ongoing costs of a technology were provided for and paid for by the implementing organization.

Combining these attribute concepts together reduced the number of attributes from 32 to 21 and also reordered the attributes based on the modified frequencies as depicted in the table 5:

Attribute	Frequency	Percentage
Acceptability and User Satisfaction	76	59%
Usefulness	67	52%
Accuracy	61	47%
Architecture and Type of System	57	44%
Data Quality	56	43%
Timeliness	46	36%
Costs	46	36%
Data Management and Interoperability	46	36%
Data Analysis and Data Visualization	46	36%
Organizational and Social	26	20%
Supportability and Compatibility	26	20%
Description and Documentation	25	19%
Performance and Efficiency	24	19%
Flexibility	22	17%
Stability and Reliability	22	17%
Data Dissemination	22	17%
Standardization	22	17%
Security and Privacy	19	15%
Simplicity vs. Complexity	10	8%
Portability	8	6%
Ethical and Legal	4	3%

Table 5 Harmonized Attributes

This resulted in the following five attributes in the first quartile and therefore included in the tool developed in Stage 3: Acceptability and User Satisfaction, Usefulness, Accuracy, Architecture and Type of System, Data Quality. Out of the six attributes in the second quartile, the reviewer only included four within the tool developed in Stage 3: Timeliness; Costs; Organizational and Social; Supportability and Compatibility. Although Data Management and Data Analysis were widely used, they are not applicable to all technologies (algorithmic processing or pure computational tasks) and can be reflected within the Architecture attribute. They will still be included in the list of optional attributes in case an evaluator determines that they are a high enough priority to include.

The Organizational and Social attribute is important for representing the ability of a technology to apply within an evaluator's organization and meeting the social needs within an organization. This is important as public health work force capabilities vary greatly among organizations so that a technology that is appropriate for one organization with well trained and well supported personnel and infrastructure may not be appropriate for a different organization with limited resources. Because organizations differ, this attribute will be used to describe the ability of a technology to meet the needs of a particular organization.

The remaining twelve attributes will not be included in the recommended attribute set in the evaluation tool, but will be included in a tool appendix that will include all optional attributes and descriptions. Optional attributes can be included to change the overall weighting of attributes used for a technology's evaluation.

Stage 3: Tool development project

The purpose of the evaluation tool is to provide a structure for evaluators to follow to increase consistency across technology reviews, but also to present the results of the evaluation in a manner that is easy for users of evaluations to understand.

Each evaluation will include basic information on the technology under review, contact information on the author, keywords, a graphical representation of the score for each of the nine attributes, a graphical representation of the technology on an adoption curve, a short paragraph describing each attribute under evaluation, a summary conclusion and a data representation. Each attribute receives an objective score of either positive (+1), neutral (0) or negative (-1). These scores are not meant to be used as interval values, but as ordinal values to allow for quick representation and interpretation of the evaluation.

The basic evaluation tool is presented as a short Microsoft Word document with the ability for the evaluator to expand as necessary to either include additional attributes or provide additional detail above what is contained within the basic template.

The evaluation tool uses two visualization techniques to quickly summarize the results of the evaluation: a bar chart summary of all nine attributes; the position of a technology's current adoption rate on a curve similar to the Gartner hype cycle curve [30] as shown in Figure 6.

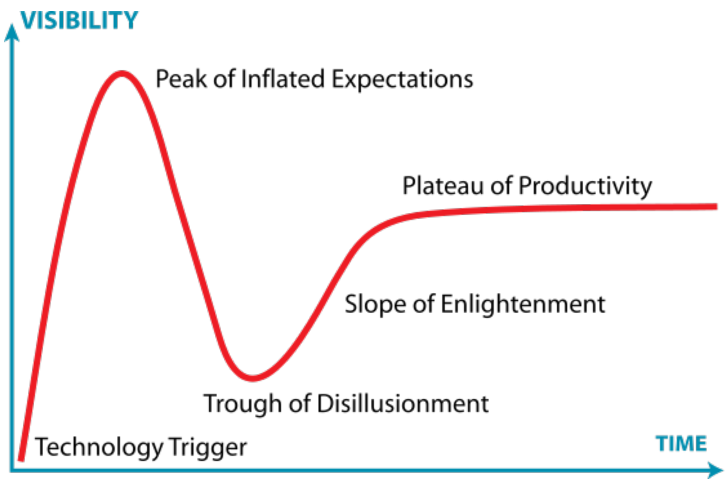


Figure 6 Gartner Hype Cycle Diagram

Jeremy Kemp / CC-BY-SA-3.0,2.5,2.0,1.0

The purpose of the adoption curve is to quickly summarize the maturity of a technology. If external technology analysts such as Gartner provide analysis of a technology, then the evaluator may accept the position as determined by the analyst or develop their own position upon the hype curve. The hype cycle consists of five different phase of a technology's life cycle: technology trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment, and plateau of productivity. The technology trigger phase is when a technology first emerges, has early success with proof of concepts but is still unproven. The peak of inflated expectations is when a new technology shows promise but early uses result in mixed success and failures. The trough of disillusionment is when a technology completes early experiments and will continue only if early adopters are able to show success. The slope of enlightenment is when technologies begin to mature and show successes. The plateau of productivity is when technologies achieve mainstream adoption. A phase not shown on Gartner's hype cycle is retirement. If a technology is nearing obsolescence, then it should be noted by the evaluator and reflected within the appropriate attributes.

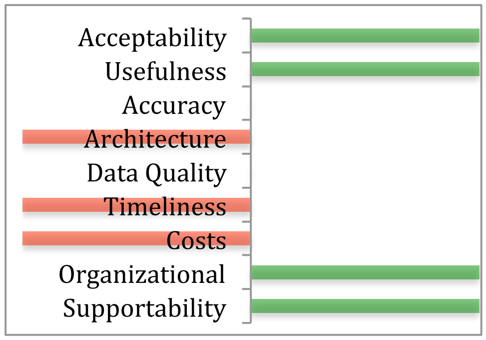


Figure 7 Example Summary Visualization
Created using Microsoft Excel

The purpose of the bar chart summary visualization is to quickly summarize the evaluation's score of each of the nine attributes to show either a red bar left of the axis representing a negative attribute assessment, no bar at the axis representing a neutral attribute assessment, or a green bar to the right of the axis representing a positive attribute assessment. Note that the summary visualization does not need to be created using a specific tool, but should clearly demonstrate each attribute used in the evaluation that is able to allow a reader to quickly see the evaluator's assessment of the technology. Two example visualizations (Figures 7 and 8) were created using Microsoft Excel and Tableau Desktop, the tool evaluated in the sample evaluation. Free and low cost alternatives to these two analysis tools are available in LibreOffice and Google Docs Spreadsheet tools.

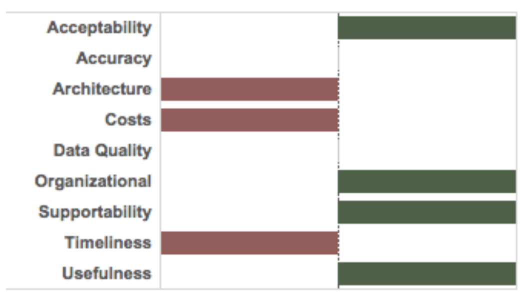


Figure 8 Example Summary Visualization
Created using Tableau Desktop

Each evaluation includes a set of author defined keywords to categorize the type of functions provided by the technology. These keywords are author defined, but they should be selected after reviewing keywords used within other evaluations. Rather than developing a hierarchy establishd by an authoritative source, evaluators contribute to a folksonomy that changes over time based on the usage and behavior of participating evaluators. A folksonomy is a classification method where content is organized collaboratively by users creating and changing tags to annotate objects and content over time [19]. Folksonomies differ from Taxonomies as there is not a hierarchical order that is accepted prior to use.

In order to encourage the sharing and use of completed evaluations, each evaluation includes a data represtation in JavaScript Object Notation (JSON) format to allow for data to be discovered and used via programmed tools. Each evaluator needs to create a JSON data string in the format shown in Figure 9 that summarizes the evaluation and includes a URL to the evaluation:

```
{
    "evaluation": {
        "url": "url-value",
        "technology": "technology-value",
        "version": "version-value",
        "keywords": [
            "keyword1",
            "keyword2",
            "etc"
        ],
        "author": "author-contact",
        "acceptability": "rating",
        "usefulness": "rating",
        "accuracy": "rating",
        "architecture": "rating",
        "data-quality": "rating",
        "timeliness": "rating",
        "costs": "rating",
        "organizational": "rating",
        "supportability": "rating"
    }
}
```

Figure 9 - Example JSON Data Structure

To help compensate for the inherent bias of the evaluator, each evaluation must be noted with the unique contact information for the evaluator. The specific format is not important, but unique handles that allow for easy communication with the author include Twitter.com handles, email addresses or any other preferred method of the author. This allows users of evaluations to learn the specific evaluation patterns of specific authors and choose to only follow specific authors, or to weight evaluations by particular authors more than others.

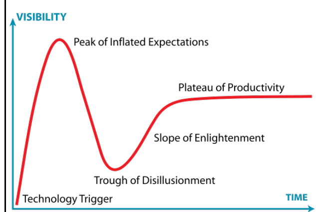
Although not required, evaluators need to be encouraged to include a unique URL where their evaluation is available. Having evaluations available through the World Wide Web makes sharing evaluations and reusing evaluations easier by being able to be shared natively through social media. The particular web site format is not important and authors can use any of the myriad available free web site tools such as blogger.com, tumblr.com, github.com or others. Another benefit of having each evaluation available on the World Wide Web means that search engines will index the evaluations and users can look for evaluations by searching for the Google-unique and Bing-unique expression "Structured Evaluation of Technology for Public Health." A search engine-unique expression is one that has zero results returned by searching for this expression. By including this unique text string within evaluations, authors make their work easily discoverable through standard Internet search engines.

To further increase usability and discoverability, organizations or users can create catalogs of evaluations by combining together the JSON strings from one or more evaluations. Catalogs consist merely of a file name eval-catalog.json published anywhere on the World Wide Web. In the creation of this thesis the author created a simple, free catalog using the Github.com web site [42]. This web site is available under an open source license, so evaluations can be freely shared and others can contribute entries by submitting pull requests to the repository owner. Pull requests are a structured function of the Git program that allows users to easily suggest changes. Authors can review the change and, if acceptable, automatically include the change into their file.

The template includes the nine required attributes, but informaticians using the template can add additional fields from the set of optional attributes described earlier. The template is also flexible enough so that informaticians can add additional attributes that they require to evaluate the technology under inspection. Additional attributes can be routinely examined and if necessary, the template can be updated to include attributes that become relevant over time. Templates can also be customized as necessary to fit organizational needs or to develop particular editing and review workflows.

Included below is the template that will be used by evaluators to select and evaluate a technology of potential use to public health and an example evaluation that was conducted on a popular data analysis and visualization tool. The full template is included as Appendix A and includes its own appendices with additional instructions recommended and optional attributes with their descriptions to guide evaluators in completing an evaluation. The full evaluation of the Tableau Desktop tool is included as Appendix B. Only the data page from the template and example are included below for brevity.

Structured Evaluation of Technology for Public Health Template

Technology Name:	<Insert Name>	Version:	<Ver>
Reviewer:	<Insert Name and Contact Info>	<Insert Summary Rating Visualization> 	<Insert Adoption Curve Visualization> 
Date:	<Insert Date>		
Public Health Business Processes:			
<Note likely public health processes where technology will be useful.>			
Description / Purpose:			
<Describe the technology and the intended purpose that the technology aims to achieve.>			
Keywords: <Provide one or more keywords describing the type of technology>			
Recommended Attributes:			
Acceptability:	<Describe and assess the ease of use, willingness of users to implement, user interface and fit of technology.>	<Score as Color>	
Usefulness:	<Describe and assess the functionality of the technology and its ability to accomplish its functionality successfully.>	<Score as Color>	
Accuracy:	<Describe and assess the ability of the tool to accurately reflect the functionality under investigation in relation to sensitivity, validity and predictive value positive.>	<Score as Color>	
Architecture:	<Describe and assess the architectural components and fit of components within the expect public health business processes. Include security architecture.>	<Score as Color>	
Data Quality:	<Describe and assess the ability of technology to enable data quality processes. Include completeness and representativeness where appropriate.>	<Score as Color>	
Timeliness:	<Describe and assess the ability of the technology to receive data on and detect an event close to its occurrence.>	<Score as Color>	
Costs:	<Describe and assess the direct and indirect costs associated with implementation and support. Include software license model where appropriate.>	<Score as Color>	
Organizational:	<Describe and assess the use of technology and social fit within expected stakeholder groups and within public health organizations.>	<Score as Color>	
Supportability:	<Describe and assess the ease of installation, the complexity of installation and the ability to maintain the technology over time within public health.>	<Score as Color>	
Conclusion:	<Summarize the overall evaluation and include recommended usage scenarios for the technology use within public health.>		
Data Representation:	<Replace example representation with values specified above.> {"evaluation":{"url":"url-value", "technology":"technology-value", "version": "version-value", "keywords":["keyword1","keyword2","etc"], "author":"author-contact", "acceptability":"rating", "usefulness":"rating", "accuracy":"rating", "architecture":"rating", "data-quality":"rating", "timeliness":"rating", "costs":"rating", "organizational":"rating", "supportability":"rating"}}		

Example Structured Evaluation of Technology for Public Health: Tableau Desktop

Technology Name:	Tableau Desktop [link for more info]	Version:	8.2
Reviewer:	Brian Lee @leebrian		
Date:	10/14/2014		
Public Health Processes:			
Diverse alignment across public health processes, but specifically "Process, Store and Analyze Data."			
Description / Purpose:			

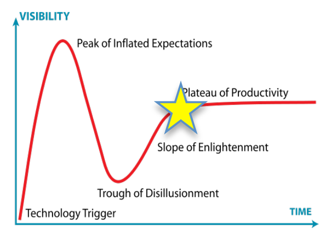


Tableau Desktop is a software tool developed by Tableau Software, a company founded out of a Stanford University project in 2003. Tableau Desktop is a visualization and analysis tool that queries data in multiple formats and provides an easy method to generate static and interactive charts, graphs and maps. Specific visualization types include: text tables, heat maps, highlight tables, symbol maps, filled maps, pie charts, horizontal bars, stacked bars, side-by-side bars, treemaps, circle views, side-by-side circles, lines, area charts, scatter plots, histograms, box-and-whisker plots, gantt, bullet graphs and packed bubbles.

Keywords: Data Analysis, Data Visualization

Recommended Attributes:

Acceptability:	Tableau has an extensive feature set that can be readily used by novice users through to expert users. Extensive training is available for free through Tableau's website and an active community forum exists to answer user questions and provide examples. Tableau Desktop is able to load data from a variety of common user formats such as comma separated value (CSV) or Excel. A professional version of the tool exists to connect to complex data sources such as MySQL, SQL Server, Google Analytics, Hadoop and other sources.	
Usefulness:	Tableau's primary purpose is to allow users to better interact with data, perform analyses and disseminate results of analyses. Tableau provides a large selection of built-in and user customizable chart times that allow customization and formatting. In addition to charts, Tableau provides US and international mapping features. Tableau creates dashboards of analysis that can be published to TableauPublic for free or to an organizationally hosted Tableau Server Edition. Tableau maintains an active release schedule with major releases every 6-12 months.	
Accuracy:	Tableau provides professional support to validate that their analytic routines calculate figures accurately. Tableau does not provide advanced regression and statistical routines that need to be carried out by statistical software.	
Architecture:	Tableau Desktop is client software that is installed on 32-bit and 64-bit Microsoft Windows workstations and Apple Macintosh workstations. Tableau also provides a Server version that provides a service application programing interface (API) that allows users of Tableau Desktop to publish and share visualizations through the web. While Server is a paid tool, Tableau also provides TableauPublic for free for visualizations and data sets that can be shared publicly.	

Data Quality:	Visualization is a useful component of data quality by allowing epidemiologists to investigate the quality characteristics of a data set. Tableau provides tools to check data for completeness and to calculate representativeness.	
Timeliness:	Tableau does not provide functionality to address timeliness and is out of scope for this evaluation. Data sources that provide data to Tableau need to be assessed for their timeliness independent of Tableau.	
Costs:	Tableau is commercial software provided by Tableau Software at charge. Tableau Desktop is available for a one-time fee of $999 per user with a $200 per user per year optional support that provides access to upgrades. A professional edition is available for a one time fee $1,999 with a $400 per user per year optional support charge that provides access to upgrades. Tableau also provides a hosted solution for $500 per user per year that includes all software installs, support and upgrades. Tableau costs are per year, not per seat or per workstation so a single user license allows the user to download, install and use the software on multiple workstations. Tableau also provides a mobile version of the tool for free that runs on Apple iOS and Google Android operating system. The mobile version does not have full functionality, but allows for viewing and interacting with dashboards.	
Organizational:	Tableau is likely to be used by epidemiologists, statisticians and public health advisors who do not have specialized informatics training. Since this is desktop software it can be used without ongoing IT support and maintenance of server components.	
Supportability:	Tableau requires no specialized support and can be maintained by its users with minimal interaction with IT support. Installation and upgrades requires temporary administrative access on Windows, but not on Macintosh. This software is currently Level III approved for use on CDC workstations.	
Conclusion:	Tableau provides an easy to use, relatively inexpensive tool for public health practitioners to use to analyze, create visualizations and effectively communicate their analysis with a diverse audience. It provides functionality common on health and non-health web sites and allows for interactivity and a pleasant user interface that other analysis tools do not require. While this tool does not replace completely statistical software packages like SAS, R and SPSS it is valuable for visualization purposes.	
Data Representation:	{"evaluation":{"url":"https://github.com/leebrian/setph/blob/master/structured-evaluation-technology-publich-health-tableau.docx", "technology":"Tableau", "version": "8.2","keywords":["Data Analysis","Data Visualization"], "author":"@leebrian", "acceptability":1, "usefulness":1, "accuracy":1, "architecture":1, "data-quality":1, "timeliness":0, "costs":1, "organizational":1, "supportability":1}}	

Chapter 5: Conclusion

Summary of study

Selecting the right technology for use within public health can be challenging to both informaticians and non-informaticians. Designers of information systems select tools for use as part of system design, but rarely is the reasoning of why they chose a tool and how successful a particular technology was within their system explained in a manner that assists other system designers. While evaluation frameworks exist to assess public health systems and evaluation is encouraged as part of informatics fellowship programs [43], the literature is missing frameworks for technology and tools that were not designed for use within public health. This study performed a systematic review of the public health literature to determine commonly used attributes for evaluation, harmonized them into a common set of attributes appropriate for evaluating technology and created a simple tool for performing and documenting evaluations.

Conclusion

While 32 attributes are commonly occurring within the health literature, analyzing frequency and harmonizing these attributes for generalizability in evaluation of technology outside of health and public health led to the selection of nine attribute concepts that are useful to all evaluations: Acceptability, Usefulness, Accuracy, Architecture, Data Quality, Timeliness, Costs, Organizational, and Supportability. Twelve additional attributes may be useful depending on the judgment of the evaluator: Data Management, Data Analysis, Documentation, Performance, Flexibility, Stability, Data Dissemination, Standardization, Security, Simplicity, Portability, and Ethical. Additional attributes can be included based on the judgment and determined need of evaluators using the tool within their organizations.

Using these attributes, identification elements and visualization elements this study developed a structured evaluation tool that can be used by informaticians to assess technologies used within routine practice or to document the assessment that goes into technology selection.

Each evaluation includes elements to summarize and visualize the technologies assessment to allow for ease of use in comparing different evaluations in the same category against each other. By selecting the naming of the evaluation tool and selecting data formats, evaluations take advantage of the structure of the Internet and the evolving nature of Internet services to make evaluations discoverable and shareable.

Implications

This research and evaluation contribute to public health informatics by encouraging the transfer of technology from outside the health, HealthIT and public health fields into public health practice. Public Health Informatics practice consists of the mixture of diverse disciplines such as computer science, information science, behavioral science, organizational science and management science when working with public health practitioners in epidemiology, surveillance and biostatistics [4]. By increasing the ability for informaticians to evaluate and share findings of how technology fits within the context of public health business processes then communication increases and public health workers have a greater selection of technologies for use within their systems, workflows and day-to-day analyses.

Recommendations

This study would be improved by extending the systematic review with additional researchers and abstracters to compare how data is extracted from public health informatics. By including more reviewers, the bias of an individual reviewer will be reduced and improved quality in the extraction of data from literature will improve the raw and harmonized attribute set. Recruiting informaticians to use the tool and share the results of their technology can then be compared against system evaluations to determine if the ability to better select reviewed technologies leads to greater fit of technology within system design and operation.

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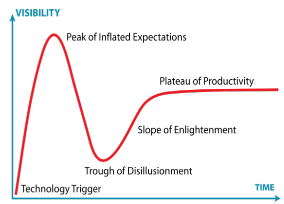
I.

Appendix A: Full Evaluation Template

Technology Name:	<Insert Name>	Version:	<Ver>
Reviewer:	<Insert Name and Contact Info>	<Insert Summary Rating Visualization> 	<Insert Adoption Curve Visualization> 
Date:	<Insert Date>		
Public Health Business Processes:			
<Note likely public health processes where technology will be useful.>			
Description / Purpose:			

<Describe the technology and the intended purpose that the technology aims to achieve.>		
Keywords: <Provide one or more keywords describing the type of technology>		
Recommended Attributes:		
Acceptability:	<Describe and assess the ease of use, willingness of users to implement, user interface and fit of technology.>	<Score as Color>
Usefulness:	<Describe and assess the functionality of the technology and its ability to accomplish its functionality successfully.>	<Score as Color>
Accuracy:	<Describe and assess the ability of the tool to accurately reflect the functionality under investigation in relation to sensitivity, validity and predictive value positive.>	<Score as Color>
Architecture:	<Describe and assess the architectural components and fit of components within the expect public health business processes. Include security architecture.>	<Score as Color>
Data Quality:	<Describe and assess the ability of technology to enable data quality processes. Include completeness and representativeness where appropriate.>	<Score as Color>
Timeliness:	<Describe and assess the ability of the technology to receive data on and detect an event close to its occurrence.>	<Score as Color>
Costs:	<Describe and assess the direct and indirect costs associated with implementation and support. Include software license model where appropriate.>	<Score as Color>
Organizational:	<Describe and assess the use of technology and social fit within expected stakeholder groups and within public health organizations.>	<Score as Color>
Supportability:	<Describe and assess the ease of installation, the complexity of installation and the ability to maintain the technology over time within public health.>	<Score as Color>
Conclusion:	<Summarize the overall evaluation and include recommended usage scenarios for the technology use within public health.>	
Data Representation:	<Replace example representation with values specified above.> {"evaluation":{"url":"url-value", "technology":"technology-value", "version": "version-value", "keywords":["keyword1","keyword2","etc"], "author":"author-contact", "acceptability":"rating", "usefulness":"rating", "accuracy":"rating", "architecture":"rating", "data-quality":"rating", "timeliness":"rating", "costs":"rating", "organizational":"rating", "supportability":"rating"}}	

Appendix A1: Required Attribute Descriptions

1. Acceptability and User Satisfaction – The willingness of users to participate and effectively use a system [25]. This attribute is sometimes included within Usefulness as it related to how the intended users of a technology are able to integrate it into practice and are satisfied with its performance and functionality.

2. Usefulness – The ability of a system to meet the objectives and priorities as designed. When possible, this attribute is used to describe by the ability of a technology to meet the disease prevention actions enabled by analysis and interpretation of the system or technology data [1]. Usefulness can also be defined as the ability of the system to meet the domain characteristics or functionality specific to this system. Evaluation should assess the ability of the system to meet the necessary functionality or accomplish its purpose. This will vary greatly depending on the type of technology and the evaluator should assess this differently depending on the type of tool. In some cases the purpose is apparent (e.g., outbreak investigation) while in other cases the evaluator may need to contact the author of the technology to gain insight.

3. Accuracy – Is the measure of how the data within a system accurately reflects the reality of data outside of a system [7]. While the sensitivity and predictive value positive attributes are specific to public health, the accuracy attribute is related but generalized to non-public health tools. This attribute represents a technology's ability to present data that accurately represents the real value

4. Architecture or Type of System – Describing the overall architecture of a technology is important for determining fit of a technology for use within a particular public health organization. This attribute is sometimes called system design or technology design and includes important characteristics like whether it uses peer-to-peer or centralized data sharing [34]. The evaluator must assess the technology in relation to their organizational context as to whether the type of system (web site, mobile application, message queue, etc.) is an appropriate fit for the architecture of other technologies that will be used within an organization.

5. Data Quality – Represents the completeness and validity of the data stored within a system or technology [21]. Data quality is a compound attributes that in some evaluations is stand-alone but in other evaluations is broken down into sub-components such as completeness, validity, and representativeness. While this is a public health specific definition for data quality, when evaluating non-public health technologies this definition must be adapted to reflect the ability of the technology to either consume or product data that is complete and error free. In many cases, a technology may provide specific benefits over improving data quality and/or reducing the number of errors or faults within the technology.

6. Timeliness – The measure of the time between initial exposure to disease agent and the ability of the user to take appropriate public health action [1]. Buehler's definition is specific for surveillance purposes, but a simplified definition is the time lapsed between when an event occurs to when a technology renders the event actionable for a user. The specific methods to measure timeliness will vary depending on the technology under evaluation but is important for comparing different technologies as to how soon a technology is useful within public health. It is important that timeliness be all inclusive to cover all aspects of timeliness that are appropriate to a technology such as onset of exposure, onset of symptoms, onset of behavior, capture of data, completion of data processing, application of analytical processing, generation of alert, initiation of investigation and initiation of public health intervention. For technologies outside of public health, some steps may not be able to be included within the specific evaluation of the timeliness attribute.

7. Costs – Cost is critical in determining the overall relative value of a technology [1] and is important in the selection of whether a technology is appropriate for use within an organization. Evaluation of the cost attribute should include both direct costs such as licensing, support, hardware, software purchases, personnel and travel; as well as indirect costs incurred across the organization for adopting a technology. The rating based on this attribute should address the

cost of a system in relation to its value or results from the usefulness attribute. This can include the value of the prevention as a result of the technology but will depend on the particular aspects of a technology. In the case of software technologies, this evaluation attribute also includes the licensing model whether it is open source, commercial or government produced software. The software license model is important for determining initial costs as well as ongoing costs for support and operation.

8. Organizational and Social – The stakeholders that use and interact with a technology on every level are critical for including within an evaluation. Including stakeholders within an evaluation provides the necessary context for understanding a system as well as providing a context for the overall evaluation results [1]. This evaluation attribute describes how a technology is adapted within an organization and addresses the social fit of the technology. This can determine how a technology is compatible with other technologies within an organization or how the technology is used differently across stakeholder groups.

9. Supportability and Compatibility – This attribute describes a system's operation and the complexity of a system in relation to how users and administrators maintain the system [1]. This attribute is sometimes included in the costs evaluation of a system. This attribute is important in determining the fit of a technology into an existing mix of technologies in an organization.

Appendix A2: Optional Attributes

Select zero or more attributes as deemed necessary to accurately evaluate the technology of interest.

O1. Data Management and Interoperability – Data management represents a variety of technology functions and features focuses on how a technology works with data within its boundaries and how data is received from and sent to outside partners. This attribute is particularly common in describing how a public health system is able to store, control access, provide access, ingest and extract data to enable to the processing of data into information. Each technology may address data management in a different manner. This attribute can be synergistic in with the attribute of standardization for how it enables interoperability with other technologies.

O2. Data Analysis and Data Visualization – Data analysis approaches are critical to the planning, creation and execution of information systems within public health [35]. While data management focuses on the structure, storage and manipulation of data; analysis and visualization focuses on the use of data to perform the necessary functions of public health. Data analysis is related to and enables other attributes like data quality (ability to analyze the data is critical to determining data quality) and timeliness (ability to visualize the data enables swifter decision making with data).

O3. Description and Documentation – It is important that a system be clearly described in overall function as well as the intended purpose that the system is trying to fulfill [1]. Each evaluation needs to include a description of the technology to give cover the purpose and intent of the system. This includes the level of documentation available for the technology and will affect the usability (i.e., clarity of documentation makes technology easier to adapt) as well as the usefulness of the system.

O4. Performance and Efficiency – This attribute describes a technology's ability to consistently and efficiently meet the demands of the users of the technology. This attribute measures the responsiveness of a technology [26] and its ability to maintain a useful level of responsiveness under expected user activity loads.

O5. Flexibility – Flexibility refers to a system or technology's ability to adapt and change as the needs of the technology's users change [1]. The evaluation of this attribute is important to determine the ability for a technology to expand and adapt to shifting organizational changes. Depending on the type of technology, this attribute will be reflected in different manners. Since technology will be used in different manners depending on its function within public health (i.e., environmental health, health policy, infectious disease, non-communicable disease, etc.) the value of a technology is greater if it can be reused in different configurations by a wide variety of users. This is particularly valuable in data intensive tools that need to adapt as data standards change over time.

O6. Stability and Reliability – Stability and reliability represent the ability of a system or technology to remain functional in variable conditions and for long periods of time within failure or unexpected periods of being offline [1]. While this definition is specific to surveillance systems, it is useful in the evaluation of technologies to describe how a technology is able to withstand unexpected performance conditions and whether it can consistently respond to the user without an interruption in service. This is important in evaluating how technologies will fit into an organization as gaps in stability and reliability can negatively impact other systems used within an organization.

O7. Data Dissemination – Systems must be able to present and share data clearly so that it can be used by decision makers and system users [35]. This attribute represents a technology's ability to accurately share information and collaborate with users of other technologies.

O8. Standardization – This attribute reflects the ability of a technology to generally recognized formats for system data that increases the ability for other systems to understand and use data produced by a system [35]. This attribute is important in determining the interoperability of a technology with other technologies but varies as to how it is important within a technology. Technologies that rely more on data interchange will require this attribute to be used with a higher priority.

O9. Security and Privacy – This attribute is largely driven by the US Health Insurance Portability and Accountability Act (HIPAA) of 1996 that describes privacy controls that are required to protect patient health information. However, this attribute is commonly included into the Usefulness or Architecture attributes of a system rather than broken out as a separate dimension of an evaluation. An evaluator may choose to prioritize this attribute is a technology is particularly sensitive to privacy or security concerns such as when a technology operates within multiple health care institutions [34].

O10. Simplicity vs. Complexity – Simplicity describes the complexity of a systems' structure as well as how easy it is for a user to operate a technology. Systems should be as simple as possible while still fulfilling their objectives [21]. The simplicity of a technology is closely related to its usability or acceptability attributes. The more complex a system is, the more difficult it is to deploy within an organization and the greater the risk that it conflicts with other technologies used. The evaluation of a system based on its complexity or simplicity will be an important factor for organizations with limited informatics expertise to support the tool and educate users on its functionality.

O11. Ethical and Legal – This attribute is important for determining whether a technology is an appropriate fit based on legal and ethical concerns of an organization using the technology or the user operating the technology [39].

O12. Portability – Portability describes how well a system can be duplicated and made useful in another setting outside of its primary setting [1]. This attribute describes the technology's ability to be reused in diverse situations. It is related to the simplicity attribute in that technologies that are simple are more likely to be portable to additional situations and organizations. This attribute is also sometimes linked to the generalizability of a technology from one specialized situation to other situations. This attribute is important for evaluators who are concerned with the ability of a single tool to be used within multiple diverse portions of their organization.

Appendix A3: Common Ground Business Processes

1. Conduct Exercise To Evaluate Organizational Response Capacity
2. Conduct Syndromic Surveillance
3. Conduct Notifiable Disease Surveillance
4. Conduct Active Surveillance
5. Conduct Public Health Investigation
6. Initiate Alerts
7. Develop And Report Situational Information
8. Manage Resources
9. Develop And Initiate Risk Communication
10. Administer Medical Countermeasures (MCMS)
11. Data Collection
12. Data Management
13. Process, Store, And Analyze Data
14. Conduct Epidemiological Research
15. Community Health Assessment
16. Develop Strategic Plan
17. Identify And Deploy Health Guidelines
18. Deliver Programs And Services
19. Develop Public Health Intervention
20. Link Individuals/Populations To Programs/Services
21. Develop And Implement Program Evaluation

Appendix B: Full Example Evaluation of Tableau Desktop Using Evaluation Template

Technology Name:	Tableau Desktop [link for more info]	Version:	8.2
Reviewer:	Brian Lee @leebrian		
Date:	10/14/2014		
Public Health Processes:			
Diverse alignment across public health processes, but specifically "Process, Store and Analyze Data."			
Description / Purpose:			

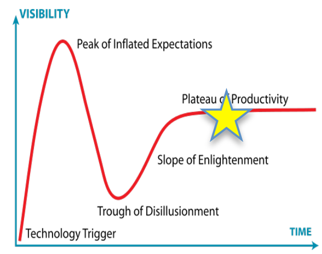


Tableau Desktop is a software tool developed by Tableau Software, a company founded out of a Stanford University project in 2003. Tableau Desktop is a visualization and analysis tool that queries data in multiple formats and provides an easy method to generate static and interactive charts, graphs and maps. Specific visualization types include: text tables, heat maps, highlight tables, symbol maps, filled maps, pie charts, horizontal bars, stacked bars, side-by-side bars, treemaps, circle views, side-by-side circles, lines, area charts, scatter plots, histograms, box-and-whisker plots, gantt, bullet graphs and packed bubbles.		
Keywords: Data Analysis, Data Visualization		
Recommended Attributes:		
Acceptability:	Tableau has an extensive feature set that is able to be readily used by novice users through to expert users. Extensive training is available for free through Tableau's website and an active community forum exists to answer user questions and provide examples. Tableau Desktop is able to load data from a variety of common user formats such as comma separated value (CSV) or Excel. A professional version of the tool exists to connect to complex data sources such as MySQL, SQL Server, Google Analytics, Hadoop and other sources.	
Usefulness:	Tableau's primary purpose is to allow users to better interact with data, perform analyses and disseminate results of analyses. Tableau provides a large selection of built-in and user customizable chart times that allow customization and formatting. In addition to charts, Tableau provides US and international mapping features. Tableau creates dashboards of analysis that can be published to TableauPublic for free or to an organizationally hosted Tableau Server Edition. Tableau maintains an active release schedule with major releases every 6-12 months.	
Accuracy:	Tableau provides professional support to validate that their analytic routines calculate figures accurately. Tableau does not provide advanced regression and statistical routines that need to be carried out by statistical software.	
Architecture:	Tableau Desktop is client software that is installed on 32-bit and 64-bit Microsoft Windows workstations and Apple Macintosh workstations. Tableau also provides a Server version that provides a service application programing interface (API) that allows users of Tableau Desktop to publish and share visualizations through the web. While Server is a paid tool, Tableau also provides TableauPublic for free for visualizations and data sets that can be shared publicly.	

Data Quality:	Visualization is a useful component of data quality by allowing epidemiologists to investigate the quality characteristics of a data set. Tableau provides tools to check data for completeness and to calculate representativeness.	
Timeliness:	Tableau does not provide functionality to address timeliness and is out of scope for this evaluation. Data sources that provide data to Tableau need to be assessed for their timeliness independent of Tableau.	
Costs:	Tableau is commercial software provided by Tableau Software at charge. Tableau Desktop is available for a one-time fee of $999 per user with a $200 per user per year optional support that provides access to upgrades. A professional edition is available for a one time fee $1,999 with a $400 per user per year optional support charge that provides access to upgrades. Tableau also provides a hosted solution for $500 per user per year that includes all software installs, support and upgrades. Tableau costs are per year, not per seat or per workstation so a single user license allows the user to download, install and use the software on multiple workstations. Tableau also provides a mobile version of the tool for free that runs on Apple iOS and Google Android operating system. The mobile version does not have full functionality, but allows for viewing and interacting with dashboards.	
Organizational:	Tableau is likely to be used by epidemiologists, statisticians and public health advisors who do not have specialized informatics training. Since this is desktop software it is able to be used without ongoing IT support and maintenance of server components.	
Supportability:	Tableau requires no specialized support and can be maintained by its users with minimal interaction with IT support. Installation and upgrades requires temporary administrative access on Windows, but not on Macintosh. This software is currently Level III approved for use on CDC workstations.	
Conclusion:	Tableau provides an easy to use, relatively inexpensive tool for public health practitioners to use to analyze, create visualizations and effectively communicate their analysis with a diverse audience. It provides functionality common on health and non-health web sites and allows for interactivity and a pleasant user interface that other analysis tools do not require. While this tool does not replace completely statistical software packages like SAS, R and SPSS it is valuable for visualization purposes.	
Data Representation:	{"evaluation":{"url":"https://github.com/leebrian/setph/blob/master/structured-evaluation-technology-publich-health-tableau.docx", "technology":"Tableau", "version": "8.2","keywords":["Data Analysis","Data Visualization"], "author":"@leebrian", "acceptability":1, "usefulness":1, "accuracy":1, "architecture":1, "data-quality":1, "timeliness":0, "costs":1, "organizational":1, "supportability":1}}	

Appendix B1: Required Attribute Descriptions

1. Acceptability and User Satisfaction – The willingness of users to participate and effectively use a system [25]. This attribute is sometimes included within Usefulness as it related to how the intended users of a technology are able to integrate it into practice and are satisfied with its performance and functionality.

2. Usefulness – The ability of a system to meet the objectives and priorities as designed. When possible, this attribute is used to describe by the ability of a technology to meet the disease prevention actions enabled by analysis and interpretation of the system or technology data [1]. Usefulness can also be defined as the ability of the system to meet the domain characteristics or functionality specific to this system. Evaluation should assess the ability of the system to meet the necessary functionality or accomplish its purpose. This will vary greatly depending on the type of technology and the evaluator should assess this differently depending on the type of tool. In some cases the purpose is apparent (e.g., outbreak investigation) while in other cases the evaluator may need to contact the author of the technology to gain insight.

3. Accuracy – Is the measure of how the data within a system accurately reflects the reality of data outside of a system [7]. While the sensitivity and predictive value positive attributes are specific to public health, the accuracy attribute is related but generalized to non-public health tools. This attribute represents a technology's ability to present data that accurately represents the real value

4. Architecture or Type of System – Describing the overall architecture of a technology is important for determining fit of a technology for use within a particular public health organization. This attribute is sometimes called system design or technology design and includes important characteristics like whether it uses peer-to-peer or centralized data sharing [34]. The evaluator must assess the technology in relation to their organizational context as to whether the type of system (web site, mobile application, message queue, etc.) is an appropriate fit for the architecture of other technologies that will be used within an organization.

5. Data Quality – Represents the completeness and validity of the data stored within a system or technology [21]. Data quality is a compound attributes that in some evaluations is stand-alone but in other evaluations is broken down into sub-components such as completeness, validity, and representativeness. While this is a public health specific definition for data quality, when evaluating non-public health technologies this definition must be adapted to reflect the ability of the technology to either consume or product data that is complete and error free. In many cases, a technology may provide specific benefits over improving data quality and/or reducing the number of errors or faults within the technology.

6. Timeliness – The measure of the time between initial exposure to disease agent and the ability of the user to take appropriate public health action [1]. Buehler's definition is specific for surveillance purposes, but a simplified definition is the time lapsed between when an event occurs to when a technology renders the event actionable for a user. The specific methods to measure timeliness will vary depending on the technology under evaluation but is important for comparing different technologies as to how soon a technology is useful within public health. It is important that timeliness be all inclusive to cover all aspects of timeliness that are appropriate to a technology such as onset of exposure, onset of symptoms, onset of behavior, capture of data, completion of data processing, application of analytical processing, generation of alert, initiation of investigation and initiation of public health intervention. For technologies outside of public health, some steps may not be able to be included within the specific evaluation of the timeliness attribute.

7. Costs – Cost is critical in determining the overall relative value of a technology [1] and is important in the selection of whether a technology is appropriate for use within an organization. Evaluation of the cost attribute should include both direct costs such as licensing, support, hardware, software purchases, personnel and travel; as well as indirect costs incurred across the organization for adopting a technology. The rating based on this attribute should address the

cost of a system in relation to its value or results from the usefulness attribute. This can include the value of the prevention as a result of the technology but will depend on the particular aspects of a technology. In the case of software technologies, this evaluation attribute also includes the licensing model whether it is open source, commercial or government produced software. The software license model is important for determining initial costs as well as ongoing costs for support and operation.

8. Organizational and Social – The stakeholders that use and interact with a technology on every level are critical for including within an evaluation. Including stakeholders within an evaluation provides the necessary context for understanding a system as well as providing a context for the overall evaluation results [1]. This evaluation attribute describes how a technology is adapted within an organization and addresses the social fit of the technology. This can determine how a technology is compatible with other technologies within an organization or how the technology is used differently across stakeholder groups.

9. Supportability and Compatibility – This attribute describes a system's operation and the complexity of a system in relation to how users and administrators maintain the system [1]. This attribute is sometimes included in the costs evaluation of a system. This attribute is important in determining the fit of a technology into an existing mix of technologies in an organization.

Appendix B2: Optional Attributes

Select zero or more attributes as deemed necessary to accurately evaluate the technology of interest.

O1. Data Management and Interoperability – Data management represents a variety of technology functions and features focuses on how a technology works with data within its boundaries and how data is received from and sent to outside partners. This attribute is particularly common in describing how a public health system is able to store, control access, provide access, ingest and extract data to enable to the processing of data into information. Each technology may address data management in a different manner. This attribute can be synergistic in with the attribute of standardization for how it enables interoperability with other technologies.

O2. Data Analysis and Data Visualization – Data analysis approaches are critical to the planning, creation and execution of information systems within public health [35]. While data management focuses on the structure, storage and manipulation of data; analysis and visualization focuses on the use of data to perform the necessary functions of public health. Data analysis is related to and enables other attributes like data quality (ability to analyze the data is critical to determining data quality) and timeliness (ability to visualize the data enables swifter decision making with data).

O3. Description and Documentation – It is important that a system be clearly described in overall function as well as the intended purpose that the system is trying to fulfill [1]. Each evaluation needs to include a description of the technology to give cover the purpose and intent of the system. This includes the level of documentation available for the technology and will affect the usability (i.e., clarity of documentation makes technology easier to adapt) as well as the usefulness of the system.

O4. Performance and Efficiency – This attribute describes a technology's ability to consistently and efficiently meet the demands of the users of the technology. This attribute measures the responsiveness of a technology [26] and its ability to maintain a useful level of responsiveness under expected user activity loads.

O5. Flexibility – Flexibility refers to a system or technology's ability to adapt and change as the needs of the technology's users change [1]. The evaluation of this attribute is important to determine the ability for a technology to expand and adapt to shifting organizational changes. Depending on the type of technology, this attribute will be reflected in different manners. Since technology will be used in different manners depending on its function within public health (i.e., environmental health, health policy, infectious disease, non-communicable disease, etc.) the value of a technology is greater if it can be reused in different configurations by a wide variety of users. This is particularly valuable in data intensive tools that need to adapt as data standards change over time.

O6. Stability and Reliability – Stability and reliability represent the ability of a system or technology to remain functional in variable conditions and for long periods of time within failure or unexpected periods of being offline [1]. While this definition is specific to surveillance systems, it is useful in the evaluation of technologies to describe how a technology is able to withstand unexpected performance conditions and whether it can consistently respond to the user without an interruption in service. This is important in evaluating how technologies will fit into an organization as gaps in stability and reliability can negatively impact other systems used within an organization.

O7. Data Dissemination – Systems must be able to present and share data clearly so that it can be used by decision makers and system users [35]. This attribute represents a technology's ability to accurately share information and collaborate with users of other technologies.

O8. Standardization – This attribute reflects the ability of a technology to generally recognized formats for system data that increases the ability for other systems to understand and use data produced by a system [35]. This attribute is important in determining the interoperability of a technology with other technologies but varies as to how it is important within a technology.

Technologies that rely more on data interchange will require this attribute to be used with a higher priority.

O9. Security and Privacy – This attribute is largely driven by the US Health Insurance Portability and Accountability Act (HIPAA) of 1996 that describes privacy controls that are required to protect patient health information. However, this attribute is commonly included into the Usefulness or Architecture attributes of a system rather than broken out as a separate dimension of an evaluation. An evaluator may choose to prioritize this attribute is a technology is particularly sensitive to privacy or security concerns such as when a technology operates within multiple health care institutions [34].

O10. Simplicity vs. Complexity – Simplicity describes the complexity of a systems' structure as well as how easy it is for a user to operate a technology. Systems should be as simple as possible while still fulfilling their objectives [21]. The simplicity of a technology is closely related to its usability or acceptability attributes. The more complex a system is, the more difficult it is to deploy within an organization and the greater the risk that it conflicts with other technologies used. The evaluation of a system based on its complexity or simplicity will be an important factor for organizations with limited informatics expertise to support the tool and educate users on its functionality.

O11. Ethical and Legal – This attribute is important for determining whether a technology is an appropriate fit based on legal and ethical concerns of an organization using the technology or the user operating the technology [39].

O12. Portability – Portability describes how well a system can be duplicated and made useful in another setting outside of its primary setting [1]. This attribute describes the technology's ability to be reused in diverse situations. It is related to the simplicity attribute in that technologies that are simple are more likely to be portable to additional situations and organizations. This attribute is also sometimes linked to the generalizability of a technology from one specialized situation to other situations. This attribute is important for evaluators who are concerned with the ability of a single tool to be used within multiple diverse portions of their organization.

Appendix B3: Common Ground Business Processes

1. Conduct Exercise To Evaluate Organizational Response Capacity
2. Conduct Syndromic Surveillance
3. Conduct Notifiable Disease Surveillance
4. Conduct Active Surveillance
5. Conduct Public Health Investigation
6. Initiate Alerts
7. Develop And Report Situational Information
8. Manage Resources
9. Develop And Initiate Risk Communication
10. Administer Medical Countermeasures (MCMS)
11. Data Collection
12. Data Management
13. Process, Store, And Analyze Data
14. Conduct Epidemiological Research
15. Community Health Assessment
16. Develop Strategic Plan
17. Identify And Deploy Health Guidelines
18. Deliver Programs And Services
19. Develop Public Health Intervention
20. Link Individuals/Populations To Programs/Services
21. Develop And Implement Program Evaluation

Appendix C: List of Included Publications in Systematic Review

1. Aburto, N.J., et al., An evaluation of a global vitamin and mineral nutrition surveillance system. Arch Latinoam Nutr, 2013. 63(2): p. 105-13.
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3. Amin, W., et al., PaTH: towards a learning health system in the Mid-Atlantic region. J Am Med Inform Assoc, 2014. 21(4): p. 633-6.
4. Ammenwerth, E., et al., Visions and strategies to improve evaluation of health information systems. Reflections and lessons based on the HIS-EVAL workshop in Innsbruck. Int J Med Inform, 2004. 73(6): p. 479-91.
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