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Geospatial Technology for Health System Strengthening

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Abstract

The authors of this paper understand the term *Health System* to be the collection of elements (people, institutions, and resources) that contribute toward the health of individuals and communities, arrived at by the marriage of the normative definitions of Health and System. The World Health Organization developed a Health Systems Framework that includes six building blocks: service delivery, health workforce, health information systems, access to essential medicines, financing, and leadership/governance. Each building block with its corresponding influence on health outcomes, is additionally influenced by contextual factors from the built and natural environments and society. This paper explores the potential for geospatial technology to strengthen health systems using an adaptation and expansion of the WHO Health System Framework. Geospatial technology has been used widely to collect, process, analyze, and visualize location-based data for many industries, including health. Even so, the COVID-19 pandemic inspired rapid increased uptake of this technology in the health care community. The objective of this work was to review new and existing geospatial apps and solutions, developed by the global leader in geospatial technology ESRI, as prospective tools for supporting health system strengthening.

Key words: *Geospatial Technology, Health Systems, ArcGIS, Esri*

1. Introduction

The term *Health* is defined by the World Health Organization (henceforth referred to as WHO) as a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (WHO, 1946). The emphasis clearly goes beyond curative health care toward a more holistic approach to health and well-being that includes disease prevention, health promotion, and rehabilitation. Despite several critiques of this definition for being unrealistic, idealistic, and unachievable, it has shed light on the direction that providers and promoters of health should pursue.

A *system* is a term used to denote a collection of interacting or interrelated elements (people, institutions and resources) that function within a given set of rules to perform as a unified whole (Backlund, 2000). Combining the two words, *health* and *system*, a *health system* could be defined as the collection of elements that contribute toward the health of individuals and communities. There have been many efforts to operationalize and evaluate the delivery of health services from a health system perspective, in alignment with systems theory. The WHO Health System Framework which includes six building blocks, namely: service delivery, health workforce, health information systems, access to essential medicines, financing, and leadership/governance, has been a widely used framework to represent the complex interrelationship and dependency between different elements of a health system (WHO, 2007). An expanded framework which demonstrates the dynamism between different elements, and illustrates the need to focus on community health needs, including the social determinants of health, has been proposed and termed "Beyond the building blocks" (Sacks et al., 2019).

Many determinants of health, health service delivery, and health outcomes are influenced by geographical contexts, and geospatial technology has been used widely to collect, process, analyze, and visualize data associated with location and geographic contexts. The understanding of the relationship between the place a person lives, works, learns, and plays and their overall health is longstanding. In 460 BC, Hippocrates, the Father of Medicine, correlated environmental conditions, health and heartiness (Hippocrates, 460 C.E.). The great Persian physician, Al-Razi, used spatial thinking for strategic planning of hospital locations in Bagdad in about 900 CE. And a seventeenth century map of Bari, Italy provides evidence of location-based quarantines to limit the spread of plague (Khashoggi & Murad, 2020). Furthermore, the use of spatial thinking by John Snow during the 1854 cholera outbreak in London has been lauded as a key example of the value of the geographic approach (Tulchinsky, 2018) (Johns Hopkins Coronavirus Resource Center, 2022). In the contemporary, many applications of geospatial technology have supported health-related workflows, including many COVID-19 pandemic response activities. The John Hopkins COVID-19 Dashboard is probably the most well-known example (Johns Hopkins Coronavirus Resource Center, 2022), having been viewed hundreds of

billions of times (E. Geragthy & S. Breyer, personal communication, 2022).

2. Methods

It was necessary to have a conceptual framework against which the Esri tools were to be assessed. After a literature review, the following frameworks were used to synthesize a model to be used for the current assessment. Those frameworks are described below.

2.1 The WHO six building blocks framework

WHO six building blocks framework provided a powerful conceptual overview of a health system (WHO, 2007). (Figure 1, six blocks on the left). The six building blocks of a health system identified in the framework were 1. service delivery, 2. health workforce, 3. health information systems, 4. access to essential medical products, vaccines and technologies, 5. financing, and 6. leadership and

Figure 1: WHO Six Building Blocks Framework

Source: WHO, 2007 ; Resilience added by Wijesekara & Geraghty, 2022.

The four overall goals/outcomes highlighted in the framework are 1. improved health, 2. responsiveness, 3. social and financial risk protection, and 4. improved efficiency (WHO, 1946). The four desirable characteristics of a health system were 1. access, 2. coverage, 3. quality, and 4. safety.

Notably, the COVID-19 pandemic has shown the world the importance of resilience in our health systems, a concept notably missing from the WHO framework. The authors of this paper suggest including resilience as the fifth overall goal/outcome to the WHO six building blocks. (Figure 1).

2.2 The monitoring and evaluation framework for health system strengthening

WHO subsequently developed another framework to evaluate its six building blocks framework examining them as input and processes, outputs, outcomes, and impact against the indicator domains, data collection, analysis and synthesis, and communication and use, in the vertical axis

The framework is found to be a versatile tool, offering a bird's eye view of the health system from multiple points.

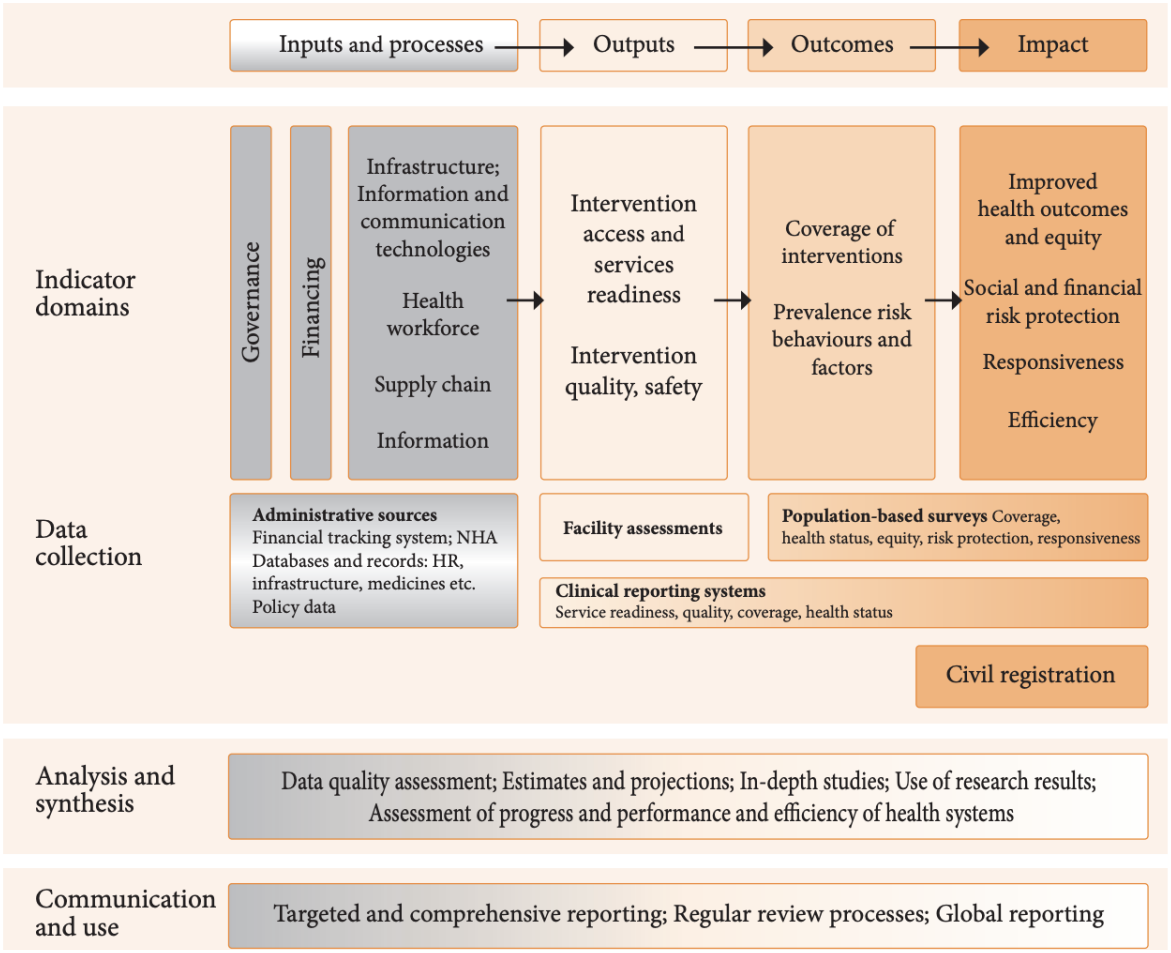

Figure 2: Monitoring and Evaluation Framework for Health Systems Strengthening

Source: WHO, 2010

2.3 'Beyond the building blocks' expanded framework

This framework, created by Sack *et al* (2019) critiques the WHO six building blocks framework as insubstantial and proposes critical elements to add for a more complete model (Figure 3). According to proponents of the Beyond the Building Blocks framework, improving the health of a population cannot be done solely through providing treatment of health care in hospitals. Health care also needs to be provided in the community, workplaces, educational institutions, households and in other health care. Further, Sack *et al* (2019) pointed out that the elements of community-based health care, as well as social determinants of health have not been clearly articulated in the WHO Health System Framework. The "Beyond the building blocks" framework seeks to be inclusive of community-based health care, household production of health, social determinants of health, community organizations and societal partnerships. Combining the three frameworks referenced, we operationalized a health system indicator domain matrix titled Geospatial Tools for Health System Strengthening (GTHSS). GTHSS is composed of 25

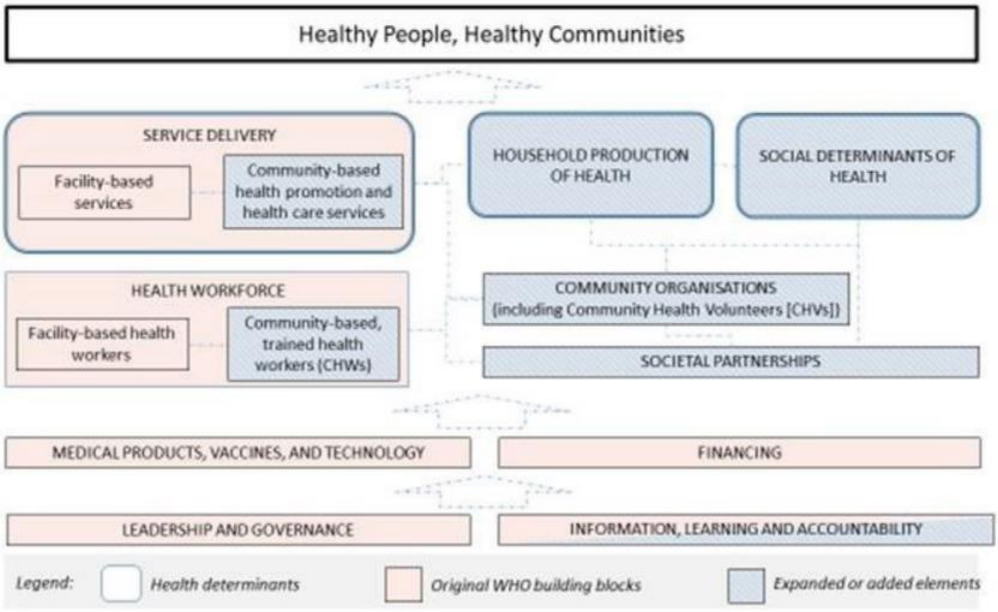

Figure 3: Beyond the Building Blocks - Expanded Framework

Source: Sack et al, 2019

grass-root endeavors (Sack *et al*, (2019). In addition, the focus should shift to preventing illnesses rather than only treating the ill. Going further upstream, as suggested by this expanded framework, it is clear that social determinants of health need to be addressed in order to achieve best possible levels of

indicator domains, namely five process building blocks, six input building blocks, four output building blocks, four outcomes, five impacts, and one goal (Table 1). If a health system is to be fully strengthened, all 25 indicator domains of the GTHSS matrix must be addressed.

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Table 1: Indicator Domains of GTHSS Matrix

Category	No	Health system building block/element	Building block/element description
Process Building Blocks	PR1	Leadership and Governance	Process of influencing and making effective relationships between all involved in the promotion of health.
	PR2	Healthcare Financing	Raising funds and allocating them for health care.
	PR3	Information Management	Collection and management of information from one or more sources and the distribution of that information to one or more audiences in relation to health systems.
	PR4	Learning Management	The process of administration, documentation, tracking, reporting, automation, and delivery of educational courses, training programs, or learning and development programs.
	PR5	Accountability Management	The acknowledgment and assumption of responsibility for actions, products, decisions, and policies including the administration, governance, and implementation within the scope of the health system and encompassing the obligation to report, explain and be answerable for resulting consequences.
Input Building Blocks	IN1	Medical Products, Vaccines and Technology	Sourcing, allocation, distribution and tracking of medicinal drugs, medical supplies, vaccines, biomedical equipment, and other supplies needed for health service delivery.
	IN2	Facility-based Health Workforce	Recruitment, allocation, distribution, orientation, and training of health staff required to deliver facility-based health services.

	IN3	Community-based Trained Health Workers	Recruitment, allocation, distribution, orientation, and training of health staff required to deliver community-based health services.
	IN4	Household-based Trained Health Workforce	Recruitment, allocation, distribution, orientation, and training of health staff required to deliver household-based health services.
	IN5	Community Organizations and Volunteers	Recruitment, allocation, distribution, orientation, and training of community organizations and volunteers to deliver facility, community or household-based health services.
	IN6	Societal Partnerships	Engagement of stakeholders in the society for preventive, promotive, curative and rehabilitative health.
Outputs	OP1	Modification of Social Determinants of Health	Identification and manipulation of economic and social conditions to minimize their negative influence on individual and group differences in health status.
	OP2	Household Level Health and Service Delivery	Delivery of health services (promotive, preventive, curative or rehabilitative) at household level.
	OP3	Community-based Health Promotion and	Delivery of health services (promotive, preventive, curative or rehabilitative) at community level.

		Service Delivery	
	OP4	Facility-based Service Delivery	Delivery of health services (promotive, preventive, curative or rehabilitative) at health facility level.
Outcome	OC1	Access	Physical and social means for accessing health services/the quality of being easy to approach, reach, enter, speak with, use, or understand.
	OC2	Coverage	Physical and social reach of the health services.
	OC3	Quality	The ability of health services to abide by predetermined standards.
	OC4	Safety	Measures available to reduce risks.
Impact	IM1	Improved Health	Achievement of desired health status.
	IM2	Responsiveness	Ability of a health system to respond to customer needs.
	IM3	Social and Financial Risk Protection	Contribution of health system for protection from social and financial risks.
	IM4	Improved Efficiency	Output per unit of input for tangible and intangible products and services delivered by the health system.
	IM5	Resilience	Ability of a health system to anticipate, prepare, respond to and recover from challenges and shocks.
Goal	G1	Healthy People - Healthy Communities	Optimized health for individuals as well as for communities.

Notes: Abbreviations: PR – Process; IN – Input; OP – Output; IM – Impact; G – Goal.

With the GTHSS matrix for health system strengthening in hand, the next step was to collect ArcGIS apps and solutions (Esri, Redlands, CA) which have been used or could be used for health system strengthening. The Health and Human Services team at Esri was consulted to prepare a potential list of software applications and pre-configured solutions that may fit the need. It was later discovered that some ArcGIS Solutions marketed for other industry sectors would also cross-over and have potential suitability for health system strengthening. Therefore, a more comprehensive review of all Esri solutions was undertaken. As the first step, the authors selected the Esri tools that they thought might be used for health system strengthening. In the next step, three technical experts from Esri (Refer acknowledgement at the end of the paper) reviewed the tools selected by the authors to exclude solutions that have already expired or would be expiring soon. During the third step, the authors evaluated each of the apps and solutions included in the study against the indicator domain matrix using a check list, with ability to assign each tool to one or more of the 25 indicator domains. As the fourth steps, the three technical experts independently validated the apps and solutions against the indicator domains. In addition, several commonly used Esri/ArcGIS tools were summarized as being used by their primary functions of (a) data collection, (b) analysis and synthesis or (c) communication and engagement stages. Three selected solutions were evaluated in detail and presented as a case study herein.

3. Results

Sixty-three (63) ArcGIS apps and solutions, out of 149 reviewed, were found to apply to one or more indicator domains. Three tools were excluded when found to be in a deprecation process. As such, the authors identified a total of 60 ArcGIS tools with capabilities aligned to strengthening at least one of the 25 indicator domains (Table 2).

We summed the number of indicator domains that each ArcGIS app or solution had potential to support (Figure 4).

Table 2: ArcGIS Apps and Solutions by Indicator Domain

Matrix for Evaluation of Esri/ArcGIS Tools/Applications for Health-Systems Strengthening																									
		Process Building Blocks					Input Building Blocks						Output Building Blocks				Outcomes				Impacts					Goal
No.	ArcGIS App or Solution Name	Leadership and Governance	Healthcare Financing	Information Management	Learning Management	Accountability Management	Medical Products,Vaccines and Technology	Facility-based Health Workforce	Community-based Trained Health Workers	Household-based Trained Health Workforce	Community Orgnizations and Volunteers	Societal Partnerships	Modification of Social Determinants of Health	Household Level Health and Service Delivery	Community-based Health Promotion and Service Delivery	Facility-based Service Delivery	Access	Coverage	Quality	Safety	Improved Health	Responsiveness	Social and Financial Risk Protection	Improved Efficiency	Resilience	Healthy People - Healthy Communities
		PR1	PR2	PR3	PR4	PR5	IN1	IN2	IN3	IN4	IN5	IN6	OP1	OP2	OP3	OP4	OC1	OC2	OC3	OC4	IM1	IM2	IM3	IM4	IM5	G1
1	Vaccine Coverage Analysis Solution					x	x	x	x		x	x	x		x	x	x	x			x	x	x	x		x
2	Community Health Assessment Solution			x		x	x						x		x	x					x	x	x		x	x
3	Social Equity Analysis	x					x	x	x		x		x		x		x	x			x	x	x			x
4	Coronavirsu Vaccine Distribution Dashboard	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x		x	x
5	Community Health Outreach	x		x	x	x		x	x	x	x	x			x	x	x	x	x		x	x		x		x
6	Coronavirus Health Screening Solution						x						x	x		x				x	x	x			x	x
7	Community Contact Tracing tools			x			x	x	x	x		x	x	x	x	x				x	x	x	x			x
8	Chime Geoprocessing Tool	x				x	x	x				x	x			x		x	x	x		x	x		x	x
9	Location Allocation (Network analysis)					x		x	x			x	x		x	x	x	x	x	x	x	x	x		x	x
10	Esri COVID-1 Pulse			x		x			x			x			x		x	x							x	x
11	Esri Demographics	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
12	Network Analysis and Optimization					x		x	x			x	x		x	x	x	x	x	x	x	x	x		x	x
13	ArcGIS Hub	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x			x	x				x
14	Citizen Problem Reporter	x		x							x	x										x			x	x
15	Business Continuity Planner			x																x		x			x	x
16	Coronavirus Force Readiness	x		x				x								x										x
17	Coronavirus Health Screening						x						x	x		x				x	x	x			x	x
18	Coronavirus Response			x											x							x				x
19	Coronavirus Testing Sites			x		x	x	x									x	x	x	x	x	x		x		x
20	Coronavirus Vaccine Outreach			x			x						x				x	x	x		x					x
21	Damage Assessment	x		x		x					x	x		x						x		x		x	x	x
22	Emergency Management Operations	x		x		x									x		x	x		x	x			x	x	x
23	My Neighborhood Services	x		x											x						x		x			x
24	Vision Zero	x		x		x						x			x					x	x		x		x	x
25	Park Infrastructure Management	x		x												x							x			x
26	Business Resilience	x		x											x					x		x				x
27	Address Data Management			x										x												x
28	AED Inventory			x		x										x	x	x	x	x	x	x	x	x		x
29	ADOPT-A-CATCH Basin	x		x		x					x	x			x					x					x	x
30	ADOPT-A-STOP	x		x							x	x			x					x					x	x
31	Citizen Problem Reporter	x		x		x						x			x					x		x				x
32	Code Enforcement Operations			x		x								x						x		x				x
33	Environmental Analysis			x											x						x	x			x	x
34	Hospitalization and PPE Inventory	x	x	x		x		x	x							x	x			x	x		x	x		x
35	Mosquito Surveillance			x		x									x	x	x			x	x	x			x	x
36	Mosquito Service Requests			x		x						x		x			x	x			x					x
37	Mosquito Treatments			x		x									x		x	x			x					x
38	My Trash Services			x		x								x			x	x			x					x
39	My Neighborhood Services			x		x																				x
40	Neighborhood Early Warning			x											x				x		x	x	x		x	x
41	Operations Management	x		x		x										x					x			x		x
42	Opioid Epidemic Outreach	x		x				x	x		x	x			x		x			x	x		x			x
43	Outage Damage Assessment			x												x										x
44	Participatory Budgeting		x	x											x						x	x				x
45	Performance Management			x		x									x		x		x	x			x	x	x	x
46	Racial Equity Community Outreach	x				x							x		x		x	x			x		x			x
47	Resource Management	x		x		x									x	x										x
48	Shelter Locator	x		x				x								x	x	x		x	x	x			x	x
49	Special Event Operations	x		x											x	x				x						x
50	Traffic Crash Analysis	x		x		x									x					x	x		x			x
51	Warming and Cooling Centers	x		x				x								x	x	x		x	x	x			x	x
52	ArcGIS Desktop			x			x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
53	ArcGIS Enterprise	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
54	ArcGIS Field Apps (Survery123, Field Maps)		x	x		x	x	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x	x	x
55	ArcGIS Online	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
56	ArcGIS Insights			x			x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
57	ArcGIS Living Atlas		x	x		x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
58	Public Policy Maps	x	x	x			x	x	x	x	x		x	x	x	x	x	x	x		x	x	x	x	x	x
59	ArcGIS Dashboards	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
60	ArcGIS Business and Community Analyst		x	x			x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x

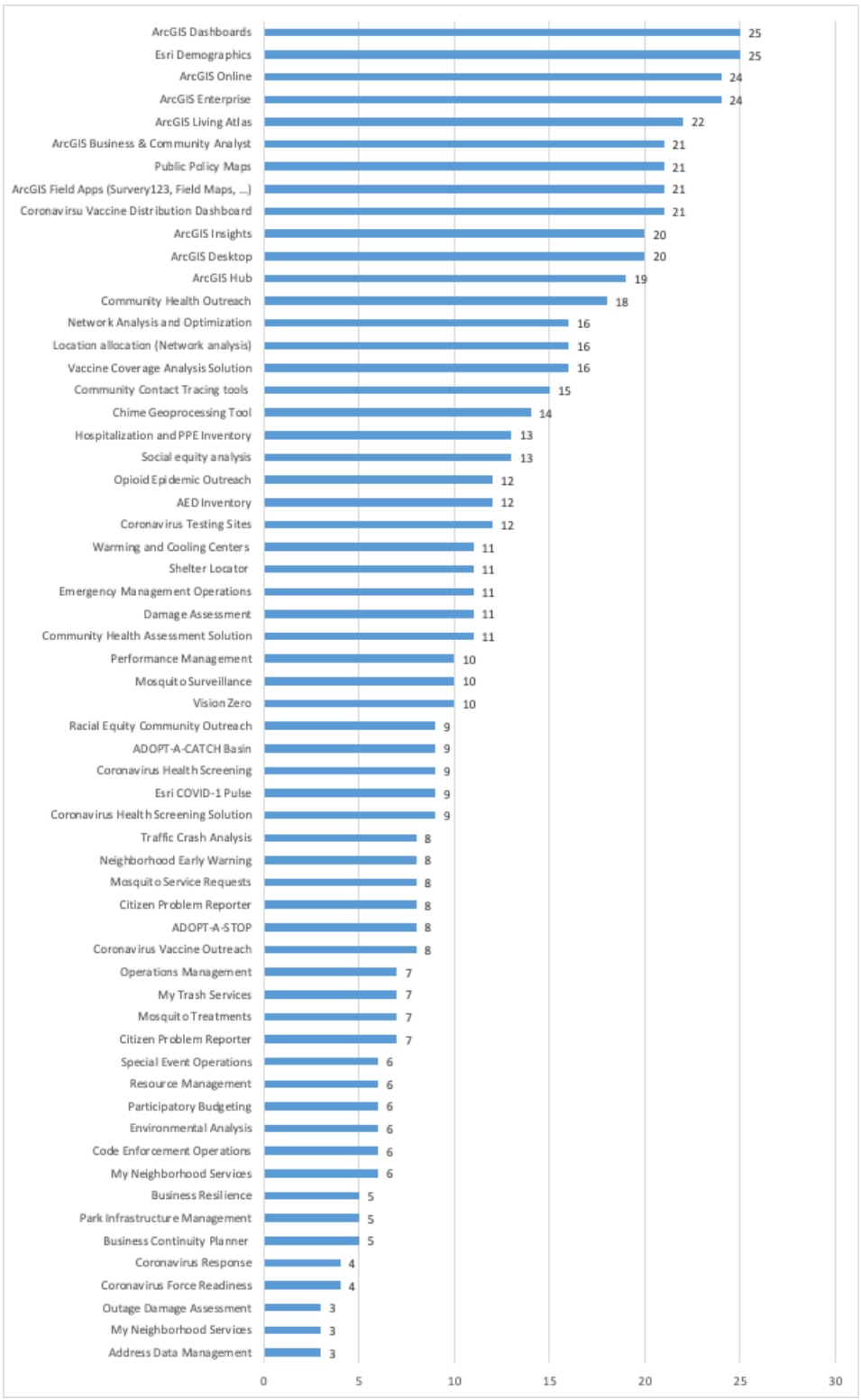

Figure 4: ArcGIS apps and solutions by the number of indicator domains that could be supported in health system strengthening efforts

As per Figure 4, it is evident that each of the 60 ArcGIS apps and solutions could be used to strengthen three or more indicator domains. Over 50% of the ArcGIS apps and solutions could be used strengthen 10 or more indicator domains. ArcGIS Dashboards and Esri Demographics could be used across all the 25 indicator domains for health system strengthening. Next, we counted the number of ArcGIS apps and solutions that were available to strengthen each of the indicator domains (Figure 5).

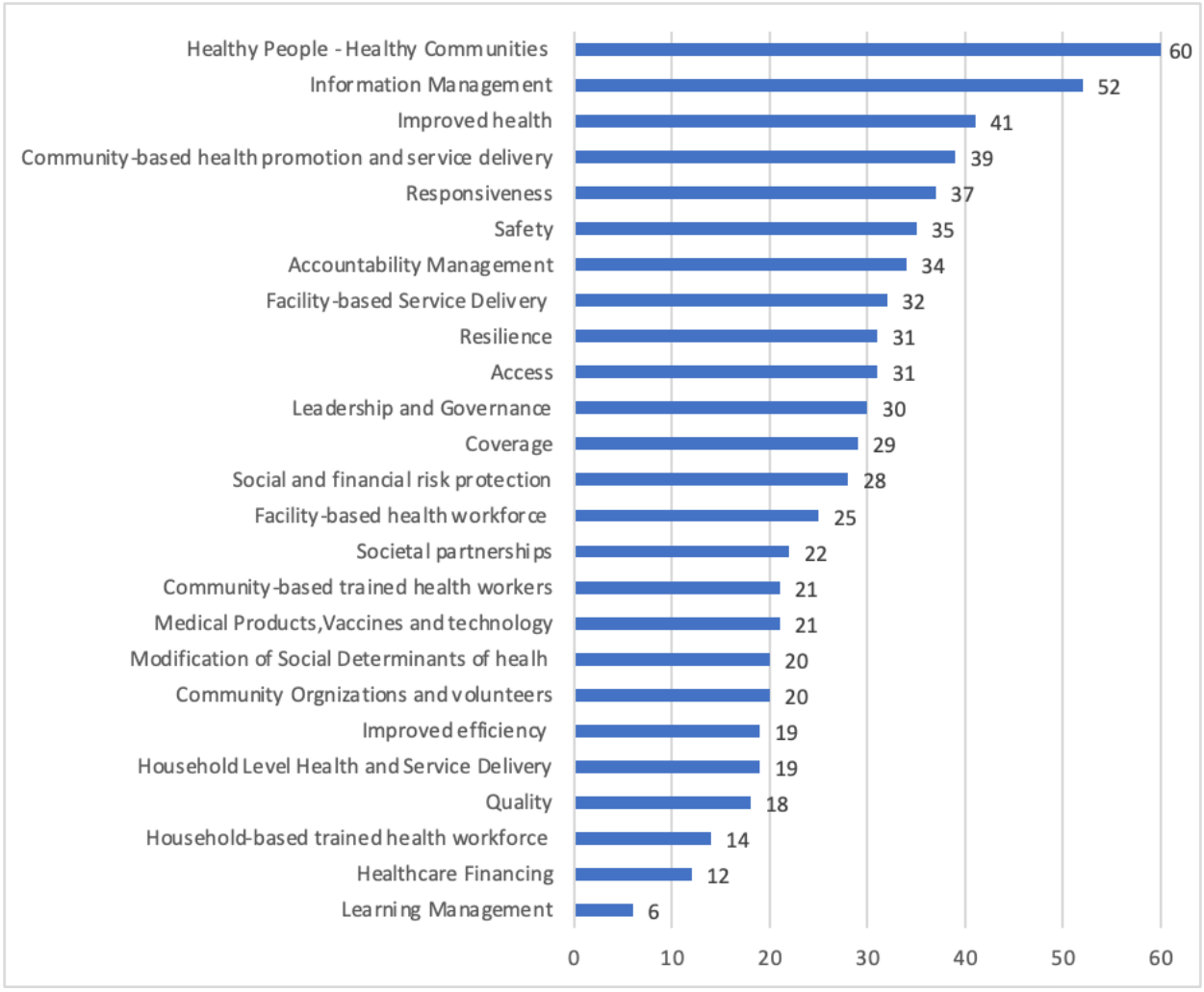

Figure 5: Number of ArcGIS apps and solutions available for strengthening each of the health system indicator domains

Any tool contributing to at least one of the indicator domains would theoretically be contributing to the overall goal of Healthy People – Healthy Communities. Hence, all ArcGIS apps and solutions were contributing to that indicator domain. Almost all tools contributed toward improved information management. It is evident from Figure 2 that the next highest number of apps and solutions have been found to support the indicator domains of Improved Health, Community-based health promotion, and Responsiveness. Except for the indicator domain of Learning Management, all other 24 indicator domains had twelve or more ArcGIS apps or solutions.

When repeatable workflows are identified in an industry area, often including the need to make complex spatial decisions, Esri may opt to create an ArcGIS Solution. ArcGIS Solutions are configured using a collection of ArcGIS apps strung together to accomplish key goals. The authors reviewed the details of the solutions to find the most frequently used native apps and categorized them into their primary functions (Figure 6).

Primary Function	Esri/ArcGIS Tools
Data Collection	ArcGIS Survey123 ArcGIS Crowdsource Manager ArcGIS Crowdsource Builder ArcGIS Field Maps ArcGIS Resource Manager
Analysis and Synthesis	ArcGIS Pro / ArcGIS Online ArcGIS Network Analyst ArcGIS Geostatistical Analyst ArcGIS Spatial Analyst ArcGIS Insights ArcGIS Business Analyst
Communication and Engagement	ArcGIS Hub ArcGIS Dashboards ArcGIS Storymaps ArcGIS Experience Builder ArcGIS WebApp Builder

Figure 6 : Commonly used Esri/ArcGIS tools by Primary Function

The primary function of data collection could be done within a health system using tools such as ArcGIS Survey123. Once data is collected, its analysis and synthesis of could be done using a

series of tools such as ArcGIS Pro or ArcGIS Online. Solutions such as ArcGIS Hub and Dashboards could be used for the communication of information as well as for the engagement of the community for decision making. Three ArcGIS solutions focused on improving COVID-19 vaccine distribution and coverage were examined in detail to see how each individually and collectively contributes to strengthening different building blocks and elements of a health system (Figure 7)

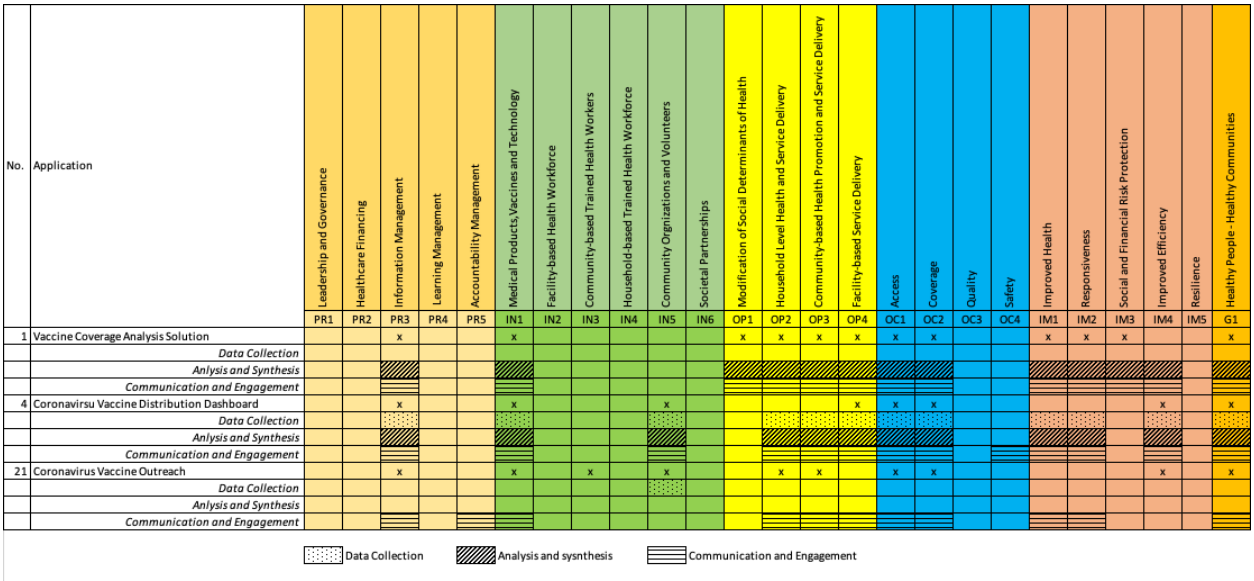

Figure 7: Review of three ArcGIS Solutions for improving COVID-19 vaccine distribution and coverage against the health system indicator domains

As per Figure 4, under each solution, three areas of the use of geospatial techniques namely, data collection, analysis and synthesis and communication and use, have been considered.

The solutions that will be explored in detail are

- Vaccine Coverage Analysis Solution
- Coronavirus Vaccine Distribution Dashboard
- Coronavirus Vaccine Outreach

The Vaccine Coverage Analysis Solution helps health and human services agencies identify priority and underserved populations, detect vaccine coverage gaps, and locate optimal vaccination sites. This solution primarily supports the analysis and synthesis and is also effective for communication and engagement areas. In addition, the Vaccine Coverage Analysis Solution helps strengthen the information management process (PR3) under the medical products, vaccines, and technology (IN1) input. Further, by optimizing access to vaccines for underserved populations, the solution contributes toward modifying social determinants of health as an output (OP1). The solution supports delivery of

COVID-19 vaccinations at the household (OP2), community (OP3), and health facility (OP3) levels, respectively. The solution is contributing to the impacts of improved health (IM1), responsiveness (IM2), social and financial protection (IM3), and improved efficiency (IM4).

The Coronavirus Vaccine Distribution Dashboard tabulates, visualizes, and monitors key vaccine distribution metrics and trends that support a phased COVID-19 vaccination plan. It uses several ArcGIS apps to engage the community members, while health authorities could use the same to communicate the vaccine distribution-related information. The said solution is used across all three areas of data collection, analysis and synthesis, and communications and engagement. In addition to covering the information management (PR3) and medical products, vaccines, and technology (IN1), the Coronavirus Vaccine Distribution Dashboard also covers the community organizations and mobilization, including volunteers (IN5), by providing an opportunity for volunteers to register to support the vaccination rollout. The solution contributes to household (OP2), community (OP3), and health-facility (OP4) level COVID-19 vaccine delivery thereby increasing access (OC1) and coverage (OC2). The solution contributes to three impacts, namely improved health (IM1), responsiveness (IM2), and efficiency (IM4).

The Coronavirus Vaccine Outreach solution is a pre-configured set of applications that are intended to communicate vaccination plans, increase public confidence in COVID-19 vaccinations, and ensure the public knows when and where they can be vaccinated. It is used for the communication and use area under information management (PR3), and accountability management (PR5) as processes as well as medical products, vaccines, and technology (IN1) as an input. It contributes to the outputs of household (OP2), community (OP3), and health facility (OP4) level service delivery. While improving access (OC1) and coverage (OC2) as outcomes, it contributes toward the improved health (IM1) and responsiveness (IM2) as impacts. It should be noted that all three solutions ultimately contribute toward the goal of healthy individuals and healthy communities (G1). Examination of the three solutions aimed at improving COVID-19 vaccine distribution and coverage demonstrate the power of helping health systems to perform better. However, since Esri/ArcGIS apps and solutions are configurable, the same ideas can be applied to other key health concerns. As an example, in the next section, we will discuss a case scenario focusing on cardiovascular disease.

Esri/ArcGIS tools for addressing cardiovascular diseases within a health system

Case Scenario

Health District A has observed a trend of increasing incidence of heart attacks over the recent years, contributing to a large proportion of the morbidity and mortality in the district. The district health authorities have been entrusted the task of addressing cardiovascular diseases within a health system in response to the rising burden of cardiovascular diseases. After a series of consultations with various stakeholders, the health district developed three strategies to be implemented in the next five years:

1. Conduct a cardiovascular risk factor survey in the health district
2. Conduct a behavior change communication program to modify cardiovascular risk factors
3. Strengthen the first contact level care for those with cardiovascular diseases and risk factors for their management, and refer to higher levels of care when needed

The possibility of using geospatial technology for addressing cardiovascular diseases within a health system to address this challenge is discussed below with the use of the Esri/ArcGIS tools. Table 3 provides brief introduction to some of the main tools used in the case scenario.

Table 3: Introduction of some Esri / ArcGIS Tools

	ArcGIS Pro ArcGIS Network Analyst ArcGIS Street Map Premium ArcGIS World Geocoder ArcGIS Spatial Analyst ArcGIS Geostatistical Analyst	ArcGIS Pro is a powerful desktop GIS application that supports data visualization; advanced analytics; and data maintenance in 2D, 3D, and 4D. This is a key application for health GIS users who need to author detailed maps, apply 1000s of spatial analytic tools, and connect results across a suite of integrated ArcGIS products such as ArcGIS Hub or ArcGIS Dashboard.
	ArcGIS Survey123	Survey123 is a complete, form-centric solution for creating, sharing and analyzing surveys. In health, this tool makes population surveys and other various data collection needs simple.
	ArcGIS Dashboards	Map-based dashboards are intuitive and interactive. With multiple ways to view your data, ArcGIS Dashboards helps health organizations monitor processes, outcomes and strategic initiatives.
	ArcGIS Hub (basic, premium)	ArcGIS Hub is an easy-to-configure community engagement platform that organizes people, data and tools through information-driven initiatives. Health hub sites range from COVID-19 vaccination information to open data sites supporting racial equity.
	ArcGIS StoryMaps	Data alone is rarely compelling. ArcGIS StoryMaps transforms your data through a digital storytelling medium. Complex health information can be shared and contextualized in more engaging ways with narrative, interactive maps, video, audio, graphics and more.

3.1 Conducting a cardiovascular risk factor survey

The decision to carry out a cardiovascular risk factor survey falls under the information management process building block (PR3). As shown in Figure 7, a range of Esri tools are available for the data collection, analysis and synthesis, and communication and engagement areas of carrying out the cardiovascular risk factor survey.

The health district planned a cardiovascular risk factor survey with the use of ArcGIS Survey123. ArcGIS Pro was used to analyze the survey data collected. The survey results were displayed with an ArcGIS Story Map including a map-based dashboard.

The aim of the cardiovascular risk factor survey was to identify potential hot spots of disease to serve as important targets for a behavior change communication program.

3.2 Conducting a behavior change communication program to modify cardiovascular risk factors

This strategy runs across many of the input and output building blocks since the health district needs to carry out this campaign at different settings such as households (OP2), communities (OP3), and hospitals (OP4). They plan to engage trained health staff serving at hospital (IN2), community (IN3) and household (IN4) levels. In addition, they are reaching out to community organizations and volunteers (IN5) to amplify and support the behavior change communication program. They are also reaching out to media and workplaces to forge partnerships to disseminate the key messages (IN5).

The health district created an ArcGIS Hub site to communicate its key messages to the public as well as to engage with them in different ways. An ArcGIS Crowdsource Manager was deployed to enable the community to gather health promoting assets available in the health district. The ArcGIS Dashboard application was used to keep the community updated on the trends in cardiovascular diseases and deaths occurring in the local area. The ArcGIS story maps application was used to document and share different behavior change interventions that communities, hospitals, and their partners support to address cardiovascular risk factors.

Further, the health authorities could use baseline information from sources such as the ArcGIS Living Atlas of the World (an Esri curated open data site), an effective behavior change communication program to modify cardiovascular risk factors. It should be noted that such baseline data is available for 139 countries, however, the amount and type may vary from place to place.

3.3 Strengthening the first contact level care for those with cardiovascular risk factors or active disease and referral processes for higher level care when needed.

This strategy addresses facility-based health service delivery (OP4) with close links to many indicators such as outcomes (access, OC1, coverage OC2), impacts (improved health (IM1), and responsiveness (IM2). Further provision of essential medicines to manage cardiovascular diseases and risk factors overlap with medicinal drugs (IN1), and healthcare financing (PR2). The facility-based health workforce (IN2) and their capacity building (PR4) for the management of non-cardiovascular risk factors and diseases also play critical roles.

Health District A used ArcGIS Survey123 to collect information about health care providers who could cater to the management of cardiovascular risk factors and diseases. ArcGIS Network Analyst was used to identify nearest health care providers to communities in need as well as proximity for referrals to provide higher levels of care. An ArcGIS Hub site was established for the patients to inquire about the healthcare providers that are available, affordable, and accessible to them. The hub which incorporates an ArcGIS Story Map was communicating easy to understand information about warning signs of cardiovascular diseases and the importance of lifestyle choices, behavior modification, and medication adherence.

4. Discussion

Health system strengthening should be a key focus over the next decade, especially with the lessons learnt from the COVID-19 pandemic. There is a need to examine health systems beyond the WHO Health System Building Blocks which has a strong focus on curative health care, without adequate attention or emphasis on community-based health care and the social determinants of health. Geospatial technology can provide a wide range of apps and solutions which could be used for health system strengthening, as evidenced from the results of this paper.

Firstly, this paper has introduced the GTHSS Matrix, which could be used for information management for the primary functions of (a) data collection, (b) analysis and synthesis or (c) communication and engagement.

Secondly, it has provided evidence to a plethora of existing geospatial apps and solutions which could be used across different health system building blocks and elements including community-based health care and the social determinants of health.

Thirdly, the results could be used to build awareness about geospatial apps and solutions for health system strengthening using terminology and concepts that are easily comprehendible by international, national, and sub-national health authorities and stakeholders.

In summary, it is evident that there are enough geospatial apps and solutions available to help strengthen health systems. Further research is needed to explore the best practices for use of such tools by health departments, as well as any barriers to uptake. Advocacy on the usefulness of geospatial tools for health system strengthening to policy leadership as well as education for operational and tactical aspects of their use needs to be done. In addition, allocation of resources for enhancing geospatial information infrastructure as well as equipping the health systems with appropriate geospatial apps and solutions in a sustainable manner should be a high priority.

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Declaration of Interest

Novil Wijesekara did a professional affiliation with Esri during his Hubert H. Humphrey Fellowship. Este Geragthy is the Chief Medical Officer at Esri.

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