DISSERTATION

INVESTIGATING THE ASSOCIATION BETWEEN PUBLIC HEALTH SYSTEM STRUCTURE AND SYSTEM EFFECTIVENESS

Submitted by

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ABSTRACT

INVESTIGATING THE ASSOCIATION BETWEEN PUBLIC HEALTH SYSTEM STRUCTURE AND SYSTEM EFFECTIVENESS

Public health systems in the United States face significant challenges due to their complexity and variability. This dissertation follows a three-paper format and examines these systems through a comprehensive analysis, using systems approaches, latent transition analysis (LTA), and ordinal regression to uncover patterns and inform improvements in public health governance and service delivery.

The first essay (Chapter 2) explores the application of systems approaches to the design and improvement of public health systems. A scoping review was conducted, revealing a paucity of literature on the use of "hard" systems methodologies like systems analysis and engineering in public health. The findings highlight the potential for systems approaches to enhance the efficiency, effectiveness, and equity of public health services. However, the limited engagement by public health practitioners and the lack of depth in existing literature indicate significant gaps that need to be addressed to fully leverage systems science in public health governance and service delivery.

Building on the literature review, the second essay (Chapter 3) introduces a novel typology of local health departments (LHDs) using LTA based on the National Association of County and City Health Officials (NACCHO) Profile study data. The LTA identified six distinct latent statuses of LHDs, characterized by variables such as governance centrality, colocation, and integration. This typology provides a robust framework for understanding the structural and

operational diversity of LHDs, offering insights into how these factors influence public health outcomes.

The final essay (Chapter 4) applies ordinal regression analyses to explore the relationship between the latent statuses of LHDs and various community health outcomes. Initial analyses using a cumulative logit model indicated a violation of the proportional odds assumption, necessitating a shift to a generalized logit model. This approach revealed significant predictors of latent statuses, such as poor physical health days, preventable hospital stays, and life expectancy. The findings underscore the complexity of public health systems and the need for careful selection of statistical models to accurately capture these dynamics. The study provides actionable insights for public health policy and strategic planning, highlighting areas for future research and potential interventions to optimize public health system design and operations.

This dissertation underscores the importance of systems approaches in understanding and improving public health systems. By leveraging advanced statistical models and exploring the structural characteristics of LHDs, it contributes to a deeper understanding of the factors influencing public health governance and service delivery. The findings offer a foundation for future research and policy development aimed at enhancing the efficiency and effectiveness of public health systems to better serve communities.

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DEDICATION

This dissertation is dedicated to my wife, Jaime Gabel, whose unwavering support and encouragement has pushed me to finish this dissertation, which has been one of the most challenging tasks I have ever undertaken, given my propensity to be a workaholic. I may not have finished this work if it were not for your constant support and direction (*I will not use the word 'badgering'*). I am excited to have completed this work so I may return to the couch with you and our two broken cats.

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Chapter 1 – Introduction

Throughout the past thirty years, there have been significant efforts to define and revitalize the United States' public health system (Institute of Medicine, 2012). The chronic underfunding and unstable budgets for public health departments, with funding allocated to specific programs on an annual basis, makes prioritization and strategic planning difficult (Institute of Medicine, 2012). As a result, there is considerable inequity in the effectiveness, efficiency and availability of public health services and "where you live" matters (DeSalvo et al., 2017). Present circumstances create a number of questions to be explored, ranging from the necessity and impact of having a more consistent governance model across public health systems to whether a conscious effort should be made to focus on fewer public health governances with greater capacity to deliver important services. Overall, there is an abundance of need for the public health sector to be better connected to other parts of the public health and medical system.

Other contextual factors have served as drivers of change to public health operations. These factors range from emergent public health crises to national governance and business trends. National initiatives and programs following the passing of the Affordable Care Act (colloquially, "Obamacare") and rise of Public Health Accreditation Board health department accreditation continue to evolve governmental public health. External pressures continue to move current paradigms toward providing fewer clinical and individual client services and more health education and population health services. Antiquated laws may not provide sufficient authority to governing institutions to tackle these contemporary issues (Institute of Medicine, 2011). Direction, however, is needed to identify priorities for public policy actions. Fortunately, the fields dedicated toward application of systems methodologies to complex issues may offer solutions for such decision-making, including the analysis and design of systems (Carey et al., 2015; Diez Roux, 2011, 2015; Kroelinger et al., 2014).

Key aspects of public health systems that lend themselves to design are their *governance, service delivery,* and *organizational infrastructure and operations* (Institute of Medicine, 1988; Mays et al., 2016; Scutchfield et al., 2009; Timsina, 2017):

Governance – The governance of a system relates to the authority and oversight of its operations and may be centralized (e.g., local units are extensions of the state) but often decentralized (e.g., local governments manage own affairs). There are a variety of governance options available to facilitate the delivery of public health services which may involve any combination of federal, state, or local governances and private organizations. Governance over service delivery may fall to a single entity or may be jointly administered, as promulgated by governing bodies.

Service Delivery – A separate but strongly related concept is service delivery which relates to how services are coordinated and which "agent(s)" act to deliver services, whether independently or in collaboration with other agencies or governances. The "agents" of delivery may be governmental public health – typically local health departments (LHDs), state health departments (SHDs), or tribal authorities – private entities through privatization of services, or a combination of multiple governments or private organizations. There are a number of mechanisms by which services may be delivered, each having different operational efficiency and effectiveness. Governing bodies have a strong role in deciding configurations of oversight and delivery and which agents deliver services.

Organizational Infrastructure and Operations – Less concrete than the prior two, the characteristics of organizations emergent from their infrastructure and operational processes are influential in collaborations with partners. The organization and processes in place affects the efficiency and effectiveness of service delivery agents. The internal structure of project teams, for instance, may dictate the ability for a jurisdiction to respond effectively to the needs of the community. Another operational consideration is the use of intra-municipal (or inter-departmental) relationships to deliver services in innovative ways, leveraging non-traditional agents with unique skillsets.

Each of these are strong determinants of the ability of a public health system to influence the health of its citizens and provide focus for this investigation. Expanded descriptions of each of these organizational features, and others, are available in **Appendix A –Overview of Relevant Public Health Concepts**.

My intent is to use systems engineering methods to inform the selection of public health governance and service delivery arrangements – both interrelated – with focuses on who participates and how services are delivered in collaborative arrangements. I will first summarize the present problem, the purpose for this study, and the significance of this study and will conclude with my approach to the investigation.

Problem

All citizens should have equitable access to at least a minimum package of public health services. However, most geopolitical jurisdictions in the nation either do not deliver the full suite of necessary services or they are delivered inefficiently or ineffectively. This may be due, in part, to the current paradigm of local governments providing services independently in a decentralized manner.

Governments within the United States are afflicted with a persistent pressure to balance the stewardship of public dollars with the competing interests of fiscal conservatism and the needs for public services. This pressure is influenced by local property tax limits, competing priorities, and other detrimental factors that contribute to budget cuts in public health. The results of this are impediments to efficiency or effectiveness of service delivery. This is further compounded by the design of geopolitical boundaries within most states and how their different governments (local, regional, and state) may or may not work together. Of additional concern is that few states have articulated in law or administrative rule a minimum package of public health services required to be available to citizens within each jurisdiction (Institute of Medicine, 2012).

I believe that the governance and configuration of different service delivery agents may be strong factors which serve to support or inhibit the performance of public health systems. As mentioned above, these facets of a public health system strongly affect the impact a public health system may have via its efficiency and effectiveness (Center for Sharing Public Health Services, 2018). The present national public health system of systems – including all federal, state, and local actors – is a disorganized decentralized system that lacks sufficient and sustainable resources as well as coordination of vision and approach. The result is a multitude of differing approaches and efficacies by geopolitical jurisdiction while prevailing health issues extend beyond jurisdictional boundaries and are subsequently addressed in a non-uniform manner. This is particularly true for public health systems at the local level ("local" in this context relates to sub-state administrative regions such as counties or cities/townships), which are a manageable subgroup for investigation within this thesis. Key variables to be considered are such things as the governance of services and mechanism of their delivery in which the different pairings of options between the two set forth mutually exclusive "statuses" or alternatives.

Purpose

The purpose of this study is to explore how a systems engineering approach toward the design of a state's public health system, including its governance structure and service delivery mechanism(s), may influence the impact of services. The study may be further refined to 1) investigate the relative strengths of governance and service delivery features on this impact; and 2) explore ways in which those features may be optimized.

This work contributes to a growing field exploring innovations in public health service delivery by thoughtful design according to typologies and system needs (Mays & Scutchfield, 2010; Mays et al, 2010; Ingram et al, 2012; Mays et al, 2017). It also builds upon research performed in areas of public-public collaboration (e.g., "cross-jurisdictional sharing") and public-private partnerships to quantify the impacts associated with decisions for governance and delivery of services (Bryson et al, 2006). Findings point toward a need for a deeper understanding of the economic, political and institutional considerations for public systems design (Hassmiller Lich et al., 2017).

This research could help policymakers understand, at the outset of exploration, which governance and service delivery alternatives are available and which may afford the best impact. Taken a step further, the study could illuminate the interactions between parts or even systems. The creation of an optimized model may evidence the benefits of considering paradigm changes for delivering public health services. The ultimate purposes for this study are to 1) inform future designs of public health systems and 2) apply systems engineering methodologies to a socio-technical system such as public health.

This will be accomplished by incorporating the systems engineering discipline to the design of public health systems, an approach not known to be utilized in this field. Leveraging systems theory (predictions for dynamic interactions between parts) and organizational theory (predictions of how organizations evolve and react), insight could be gained toward how the design of public health systems should be approached. Though, this will not be able to be answered empirically within the present investigation as it would not be possible to institute an experiment for engineering a public health system. Instead, I hypothesize that variables suggested as important from a systems engineering perspective will be shown to be related to measures of service delivery and will examine the relations among the two.

Significance

This research is significant because it will arm policy-makers and public health leaders with evidence for decision support. Policymakers may then intervene to shift governance and service delivery paradigms toward systems allowing for greater impact. This also furthers the systems engineering discipline by displaying versatility in application to socio-technical systems such as a public health system.

There is a current momentum within the public health sector to explore innovative approaches toward the governance and delivery of services, including the "modernization" of governmental public health as a means of systems transformation (Bekemeier et al., 2014). Modernization of public health relates to shifting paradigms for the requirements, interventions, and delivery of public health services. This momentum is bolstered by both paradigm shifts away from the traditional transactional services to contemporary population-based services as well as national interests, such as from the Robert Wood Johnson Foundation and Public Health Accreditation Board who fund exploration into high-impact service delivery mechanisms and who certify superior performance of public health departments, respectively.

"Soft" systems methodologies which aim to better describe problems or to mediate conflicts are widely available within literature (Checkland and Poulter, 2010). Scant evidence, however, has been found within literature for "hard" systems methodologies, such as system analysis and systems engineering, applied toward socio-technical systems such as those within public health, public management, and other public policy domains. These gaps illustrate the present limitations in the type and scope of interventions for systems change to address contemporary problems – *high-impact approaches to the problem are not perceived by policymakers and are, thus, not deployed*. This study could fill important gaps in approaches toward the design and improvement of public health services and systems and could potentially benefit other public policy domains. This may be accomplished by understanding how systems theory, paired with organizational theory, predict that public health agencies may likely pursue differentiation, integration, and concentration within delivery systems (Mays et al, 2010).

I believe that the current structures and delivery mechanisms of the present, cross-sectorial public health systems in the United States hinder their ability to address contemporary threats to the public's health. Opportunities may exist to improve upon the design of the public health sector, along with other public and private sectors, to improve efficiency and effectiveness of service delivery. This may be accomplished via methodological applications of systems theory that can garner important insight into the current problems, offer alternative interventions to address those problems, and support an infrastructure to engineer better public health systems.

Organization of Thesis

This dissertation follows a three-paper format and examines these local public health systems through a comprehensive analysis across each essay, using systems approaches, latent transition analysis, and ordinal regression to uncover patterns and inform improvements in public health governance and service delivery. The following chapters of this dissertation are organized as follows:

- Chapter 2 (Essay 1) – *System Approaches in Governmental Public Health: Findings From an Analysis of the Literature*
- Chapter 3 (Essay 2) – *A Novel Typology of Local Health Departments with Latent Statuses Derived from the NACCHO Profile Study*
- Chapter 4 (Essay 3) – *Ordinal Regression Analysis of Local Health Departments' Latent Status Across Community Health Outcomes: Insights from the NACCHO Profile Study*
- Chapter 5 - Conclusions

Separate research questions were devised for each essay according to each study's unique focus:

- <u>Essay 1 Research Question</u> – *How may a systems approach toward design of governance structure and service delivery mechanisms of a public health system improve service delivery?*
- <u>Essay 2 Research Question</u> – *How can latent transition analysis be used to classify local health departments into distinct statuses based on governance, centrality, colocation, and integration, and what are the transition probabilities between these statuses over time?*
- <u>Essay 3 Research Question</u> – *How do various community health outcomes influence the latent statuses of local health departments, as identified through latent transition analysis, and what are the significant predictors of these latent statuses through ordinal regression?*

The next chapter offers a scoping review for systems approaches in public health with subsequent chapters devising a novel typology for local public health systems, then analyzing those categorizations with respect to community health outcomes.

Chapter 2 – System Approaches in Governmental Public Health: Findings from an Analysis of the Literature[1]

Introduction

Defining, organizing, and functioning as an efficient system to improve the public's health is an ongoing challenge for the national public health enterprise. The national public health enterprise is a complex system of interrelated parts and subsystems that work together to deliver services to improve the public's health. The complexity is well-characterized — 573 federally recognized tribes, five incorporated territories, and more than 90,000 general-purpose and special-purpose governments (U.S. Census Bureau, 2019). State and local governments are generally responsible for program planning, implementation, and evaluation of service delivery at the state and local levels, leading to nearly 3,000 public health departments with the vested responsibility to protect the public's health. To add to the complexity, modern public health is a loosely-coupled system of public and private actors who work together through coordination, collaboration, and even consolidation (Trochim et al., 2006). Each of these systems developed according to local cultures and needs through an ever-shifting political landscape leading to fragmented or duplicative authorities (Institute of Medicine, 2011).

Public health's role has evolved over time in response to pressing issues, though the legal and political landscape has not always kept pace leading to confused priorities, unstable budgets, and limited authorities to act (Institute of Medicine, 2012). As exampled by responses to public health threats from hurricanes, chemicals in consumer products, and emergent diseases such as

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[1] This paper has been published in Systems Research and Behavioral Science. Citation: Orr, J. M., Leider, J. P., & Gutilla, M. J. (2022). *System approaches in governmental public health: Findings from an analysis of the literature*. Systems Research and Behavioral Science, 1–11. https://doi.org/10.1002/sres.2829.

the 2019 novel coronavirus ("COVID-19"), the national response to threats is often uncoordinated, inefficient, or ineffective. There is presently a wide variation in the governance — oversight, responsibility, and accountability for public health — and delivery of public health services across local, state, and national levels which, in turn, has reduced the ability to equitably address needs in all places with an obvious consequence: life expectancy is directly related to geography (DeSalvo et al., 2017).

Methods which investigate public health systems holistically may hold promise for designing solutions to these issues. "Systems approaches" are a means to consider alternatives and investigate optimal solutions within the context of complex networks of interactions. Defined broadly, systems approaches may include "hard systems methodologies" such as systems analysis (e.g., appraisal of costs), "soft systems methodologies" such as problem structuring methods, and also "critical systems thinking" as a pragmatic approach that leverages both hard and soft approaches (Adcock et al., 2021). The use of systems approaches in the design or redesign of the public health enterprise has been suggested in literature to be an opportunity for enhanced efficiency, effectiveness, and equity of services delivered (Carey et al., 2015; Diez Roux, 2011, 2015; Kroelinger et al., 2014). These frameworks and methods that consider a wide expanse of actors that contribute to the functioning of the system, may offer a more effective means to prepare for or respond to public health's evolving role. Of note, the systematic review by Gemma Carey and colleagues (2015) had similar aims to the present study and reported on findings from a systematic review to (1) explore how systems methodologies were being applied within public health and (2) identify fruitful areas of activity. That review identified critical shortcomings such as the limited engagement by public health practitioners but did not investigate how systems approaches may aid in designing or enhancing the governance or delivery of public health services.

Systems approaches may present an invaluable means to detect and evaluate limitations present within current paradigms of public health governance and service delivery. The present review of literature addresses the guiding research question: *How may a systems approach toward design of governance structure and service delivery mechanisms of a public health system improve service delivery?* The objective of this study is to synthesize available literature to characterize systems approaches used in current practice and illustrate how the application of approaches may enhance the governance and delivery of public health services.

Methods

A scoping review was selected to answer the research question, conducted in line with Dobbins' rapid review and Moher et al.'s PRISMA approaches (Dobbins, 2017; Moher et al., 2009). Dobbins' rapid review and the PRISMA statement provided a framework for a systematized approach toward document identification and review. The author and members of the research team followed human participants' protection guidelines; no research involving human subjects was performed in this study.

Search strategy

The search strategy aimed to obtain original peer-reviewed literature, commentaries, analytic essays, and gray literature that addressed the research question. Articles were all obtained using "Publish or Perish 7" (PoP) software (Harzing, 2007) to record and conduct replicable queries through Google Scholar (GS) and Web of Science (WoS) databases. Keyword queries each included multiple search terms from each domain to return potentially relevant articles from both GS and WoS databases in August 2019 (see **Appendix B –Scoping Review**

Query Metrics for query details and **Appendix C –Scoping Review Methodology** for search strategy details).

Study selection

There were no restrictions on study design or outcomes measured; only articles in English and published after January 2000 were considered. Study selection followed a two-phase screening and eligibility appraisal process using two independent reviewers and a third to resolve conflicts. First, citation titles and abstracts were screened for relevance to the research question. Then, full text documents of the remaining articles were reviewed according to three eligibility criteria: (1) discussion of at least one systems approach, (2) application in the public policy domain, and (3) application to governance or delivery of services; item #2 was expanded to "public policy" to include applicable cases where the search term "public health" was not included. For example, a study describing the use of network analysis to improve efficiency of public health service delivery would be eligible, while a similar study not using a systems approach would not be eligible.

The study design led to output of research articles of heterogeneous design and a primarily descriptive nature, which did not necessitate use of tools for critical appraisal and assessment of risk of bias within or between studies. No meta-analysis of study outcomes was warranted. Screening and eligibility appraisal phases included independent review by two reviewers, with a third resolving conflicts between reviewers.

Data extraction and key themes

Metadata fields from the PoP citation output (e.g., author, year) were included for all citations. More fields were added to track screening and eligibility dispositions as well as for data extraction. Summarization and theming were performed on each included material. For thematic analysis, systems approaches and applications were organized according to typology of systems approach, and application setting. As studies may discuss multiple systems approaches or applications, certain studies may represent multiple relevant items.

Each systems approach was categorized according to its analytical representation and systems method. Analytical representations described the form and function of systems approaches (e.g., descriptive model, simulation) whereas the methodology of an approach described whether the methods related to collaborative approaches for problem definition ("soft"), systems analysis and problem resolution ("hard"), or a balanced approach of investigation and solution ("pragmatic"). Then, each application setting was assorted according to the sector or area of application (e.g., public health), one or more of six governance functions, type of governance boundary (e.g., internal to organization, multi-jurisdictional), and mechanism of service delivery (e.g., independent delivery, shared delivery). The author and members of the research team then analyzed findings descriptively and reported them within tables and narrative (see **Appendix D –Scoping Review Results Summary** for detailed results).

Results

The parallel search strategy utilizing multiple different PoP searches of GS and WoS resulted in 682 citations and 702 citations, respectively (**Figure 1**). The combined sum amounted to 1384 citations, of which 1128 unique citations were kept following removal of 256 duplicates. After first screening of citation titles and abstracts against the research question, 1080 citations were excluded as not relevant. The remaining 43 documents were reviewed in full, from which 9 documents were excluded due to not meeting review criteria. Examples of typical exclusions include systems approaches exclusively focused on programmatic information systems, modeling or simulation of specific events, workplace quality or safety, epidemiology or evaluation of intervention, and other ways in which software or hardware may be used for programmatic goals. A total of 34 articles, published between 2004 and 2019, met the criteria for inclusion (see **Appendix E –Full List of Articles Included in Scoping Review**). The final articles kept for review accounted for 3% of initial unique citations and almost 80% of potentially relevant documents following screening.

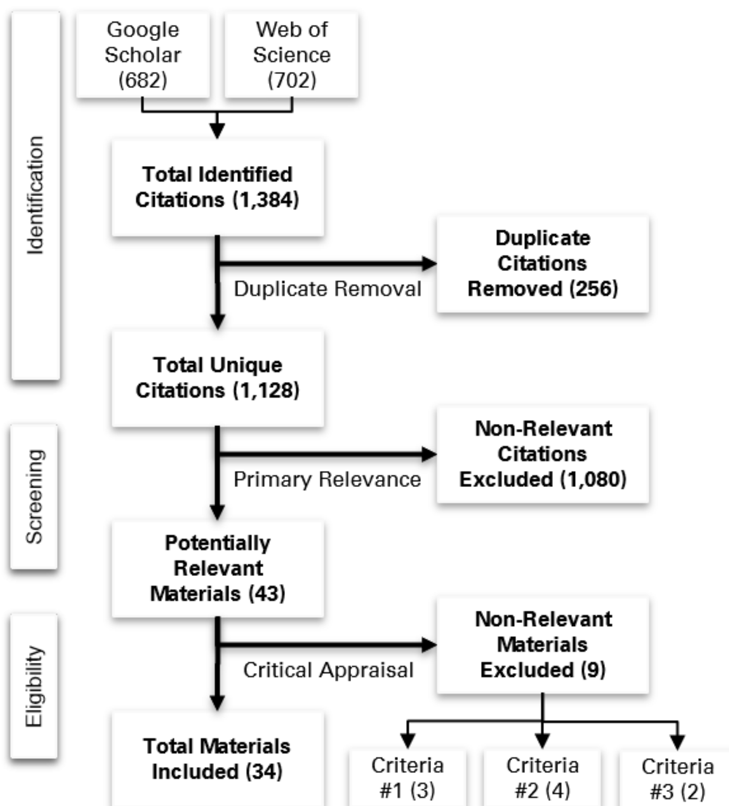

Figure 1. PRISMA Flow Diagram

Systems Approaches

A total of twenty-five unique systems approaches were discussed within the included articles and are described within a "treemap" that depicts the count of articles including a specific systems approach as a box proportional to other approaches (**Figure 2**). The concept of a "systems approach" varies widely across disciplines and may also contain or guide application of other systems approaches, such as the Levins Framework to test application of system dynamics modeling and other approaches to public policy development (Ip et al., 2013). The identified approaches encompassed a broad range of methodologies from soft methods to investigate problems (e.g., group concept mapping, public agency strategic analysis), to hard methodologies to address pre-identified problems (e.g., system dynamics modeling, the Nexus Model), to the more pragmatic methods balancing those two forms (e.g., complex systems thinking, network mapping). Though there were a wide variety of systems approaches described within studies, the majority (n = 18 approaches) were only discussed in a single material. System dynamics modeling (SDM) and complex systems thinking (CST), however, were each discussed in nearly one-fifth of studies (n = 6 articles and n = 7 articles, respectively).

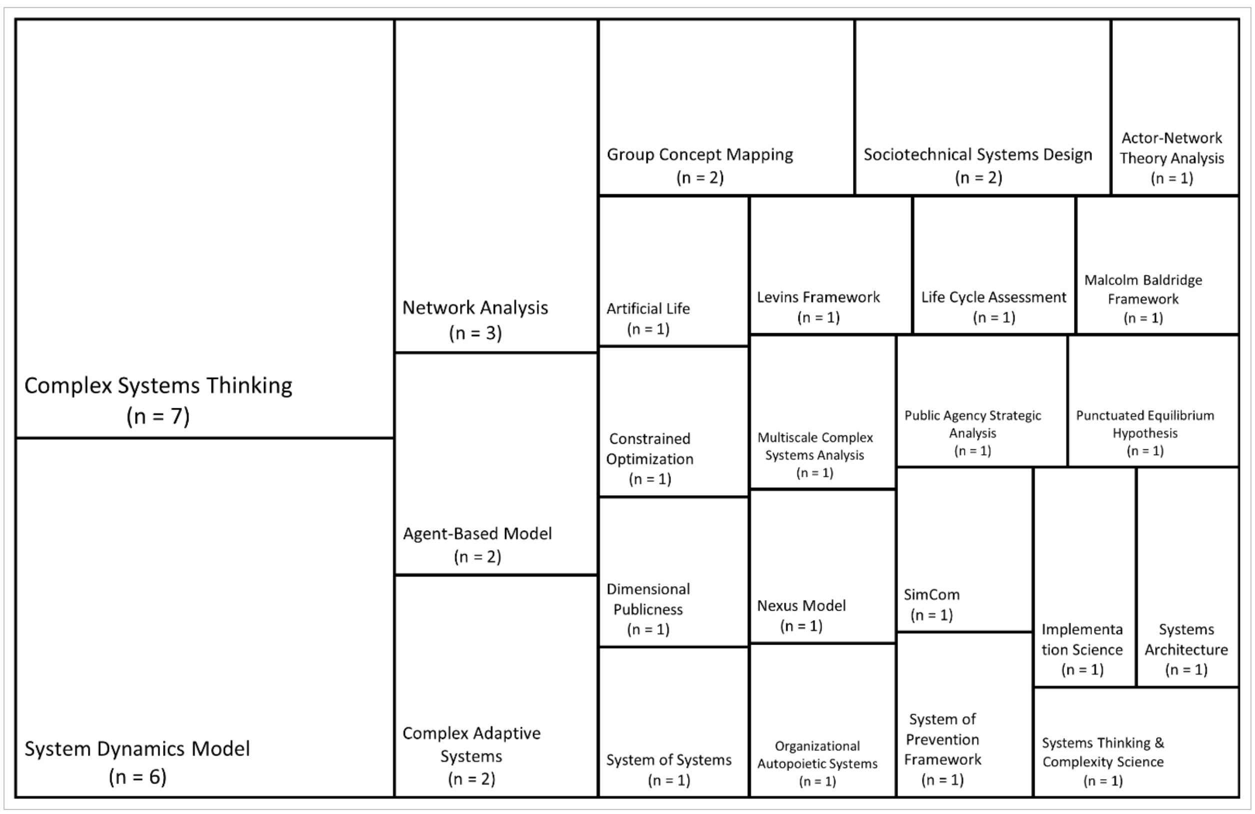

Figure 2. Treemap Identified Systems Approaches and Counts of Materials Referencing Approach

Some authors discussed systems approaches from the standpoint of general descriptive model or recommended approach (n = 19 instances) while other systems approaches were discussed as a model or simulation with firm structure and application (n = 27 instances). These approaches were applied or employed for a wide variety of purposes, as described by Ip et al, including identification or prioritization of research gaps, knowledge synthesis, system or problem heuristics, hypothesis formation, modeling or forecasting, and other virtual experimentation of scenarios (Ip et al., 2013). Relative to the present research question, these methodologies were also discussed to be used for policy analysis and design, such as in the examination of tradeoffs and dynamic scenarios, as opposed to the more common statistical methods that are firmly rooted in past performance (Ip et al., 2013). Lastly, approaches could be discussed from a theoretical basis with complexity theory observed to have the highest representation across analyzed articles (n = 17/33) and systems approaches (n = 10/25), followed by general systems theory across articles (n = 9/33) and approaches (n = 8/25).

Applications to Governance and Service Delivery

Systems approaches were seen to be applied toward the governance and delivery of services across policy domains. The broad use of search terms afforded results non-specific to but inclusive of public health as the ‘public policy’ and ‘public services’ aspects of public governance may apply to any service system. Articles which described applications to enhance general legislative and enforcement activities were categorized as ‘public policy’ and those which described applications to general government service activities were categorized as ‘public services.’

Applications According to Governance Function

Systems approaches were ascribed to one or more of the six governance functions defined by Carlson, Chilton, Corso, and Beitsch (2015): Policy Development, Resource Stewardship, Partner Engagement, Continuous Improvement, Legal Authority, and Oversight. As seen in **Table 1**, most applications were observed for Policy Development (n = 16), followed by

Continuous Improvement (n = 9) and Resource Stewardship (n = 7). Far less activity was seen for the functions of Legal Authority (n = 3) or Partner Engagement (n = 2). The governance function of Oversight was not observed to be an explicit application of any systems approach. Some approaches did not present a clearly defined application to governance or applied to more than one function and were labeled as "non-specific" (n = 4). For example, the pragmatic approach of CST was described by Diez Roux as meeting multiple disparate needs for policy development, authority over cities, and resource constraints (Diez Roux, 2011, 2015).

Table 1. Count of Approaches Ascribed According to Governance Function, Service Delivery Mechanism, and by Governance Area

Governance Function, Service Delivery Mechanism	Public Policy	Public Services	Public Health	Grand Total
Continuous Improvement		**2**	**7**	**9**
Internal (D&I)		1	2	**3**
Non-Specific		*1*	*5*	***6***
Legal Authority	**2**		**1**	**3**
Joint/Shared	1			**1**
Non-Specific	*1*		*1*	***2***
Partner Engagement		**1**	**1**	**2**
Joint/Shared		1	1	**2**
Policy Development	**10**	**2**	**4**	**16**
Internal (D&I)	1		2	**3**
Joint/Shared	1			**1**
Non-Specific	*8*	*2*	*2*	***12***
Resource Stewardship		**1**	**6**	**7**
Agent (CJS)			1	**1**
Agent (CSC)			1	**1**
Internal (D&I)			1	**1**
Joint/Shared			1	**1**
Non-Specific		*1*	*2*	***3***
Non-Specific			***4***	***4***

Applications According to Service Delivery Mechanism

Author use of systems approaches toward service delivery were less explicitly present within studies. For example, only Hunter and Perkins described using systems methods to design or enhance cross-jurisdictional (n = 1) or cross-sectoral (n = 1) service delivery (Hunter & Perkins, 2012). Most specific applications were observed for the interdepartmental or internal agency organization of services (n = 7) followed by joint or shared governance and delivery of services (n = 5). Applications not specific to any one mechanism of delivery were labeled as "non-specific" (n = 28). Of note, the studies from Luke et al and Burke et al both suggested potential applications with regard to geopolitical boundaries (e.g., city, county) and a heterogeneous mix of actors, focusing on system dynamics modeling (SDM), agent-based modeling (ABM) (Madhavan et al., 2018), and network analysis (NA) (Burke et al., 2015; Luke & Stamatakis, 2012).

Aims of Systems Approach Applications

Applications were observed to primarily meet purposes of either problem identification and decision-making or systems design and enhancement. Problem identification and decision-making comprised the majority of aims for authors' and contained more traditional systems approaches such as "constrained optimization" to determine best use of scarce resources, complex systems thinking, strategic analysis, and simulation. Systems complexity was most frequently discussed (n = 11) with multiple authors described a complex adaptive systems (CAS) perspective to decision-making in government. This was exampled in research by Head et al and Haynes et al to investigate the utility of CAS in overcoming barriers to decision-making, organizing, financing, staffing — governance functions — and also moving beyond technical or rational thinking toward collaborative leadership for service delivery (Haynes, 2017; Head & Alford, 2013; Kroelinger et al., 2014; Northridge & Metcalf, 2016; White, 2016). Another example from Kroelinger et al was seen in taking a CAS approach to advance maternal and child health planning and enhance efficiency in services delivered collaboratively from multiple departments within an agency (Kroelinger et al., 2014). SDM, used to simulate complex systems of feedback and growth, has been observed as having increased in utility over time (Ghaffarzadegan et al., 2010; Hassmiller Lich et al., 2017; Luke & Stamatakis, 2012; Schwaninger, 2008; Wheat, 2010). Lastly, compound models and paired approaches were also described by authors for use in decision-making, including

- actor-network theory (ANT) analysis: a multi-faceted approach toward decision-making for public policy that weaves together heterogeneous social networks which then diffuse decision outcomes across the networks' many links and knots (Young et al., 2010);
- group concept mapping (GCM) and system dynamics modeling (SDM): stakeholder engagement to collectively identify root problems and relationships within the system to develop dynamic models to quantify diagrammed relationships (Hassmiller Lich et al., 2017);
- the Levins framework: framework based on the work of population biologist Richard Levins which evaluates decisions according to tradeoffs made among desiderata of generality, realism, fit, and precision (Ip et al., 2013); and
- the Nexus model: a complex and multi-dimensional network of autonomous agents interconnected within an adaptive system of feedback loops which contribute to a complex system of decision-making for public policy (Dawoody, 2010).

Systems approaches used in the design or enhancement of service systems were less common. The strongest example for design or enhancement was the use of a socio-technical systems (STS) perspective to describe service systems as a complex network of interdependent social elements ("actors") and technologies, such as public infrastructure and utilities (Bauer, 2009; Patorniti et al., 2017). Systems complexity approaches such as CAS have been considered, in addition to the hybridization of governance within the context of dimensional publicness

(Bozeman, 2013; Diez Roux, 2011, 2015; Hunter & Perkins, 2012; White, 2016). A final example was observed in the research by Merrill et al in which may be a tool to identify both internal and external features for design of governance and service delivery (Merrill et al., 2008).

A variety of unique systems applications to governance and service delivery were also seen, including

- Baldridge Excellence Framework: often associated with its national quality award created in 1987 by Public Law 100-107, the framework was suggested as a means to design public health services (Kapp et al., 2017);
- System of Prevention Framework: application of systems thinking and prevention initiatives to design a multi-sectoral system (Sims & Aboelata, 2019);
- Autopoiesis: regarding organizations as abstract autopoietic systems that may independently innovate and improve themselves (Lenartowicz, 2018); and
- Multi-scale analysis & complexity profile: determine function and desirability of organizational form by pairing analytic techniques with complexity sciences (Bar-Yam, 2006).

A summary of key findings and implications are presented in **Table 2**, below.

Table 2. Summary of Study Key Findings and Implications

Key Finding	Implication
Of 1,128 unique citations, 43 documents were reviewed in full, resulting in 34 articles retained (3% of unique citations).	*The paucity of key articles identified in the review may signify a research opportunity for systems approaches applied to public health governance and/or service delivery.*
A total of 25 unique systems approaches were identified with most (n = 18) only discussed within a single article but some (e.g., system dynamics modeling, complex systems thinking) discussed in multiple studies.	*Findings suggest a wide variety of systems approaches are available to address complex problems, though, the evidence base for their utility or benefits is limited which may inhibit their consideration as a solution to complex problems.*
Approaches were found to be utilized in relatively few situations with respect to governance functions or service delivery mechanisms but used for specific functional purposes (e.g., problem definition, decision-making, systems design).	*The lack of depth or examples of their use in public health governance or service delivery inhibits informed selection for such purposes. Approaches each have specific functional uses and may be selected for use in those circumstances.*

Discussion

This scoping review aimed to address how systems approaches may be used toward the governance of public health services and how they may be delivered. The search strategy was intentionally broad, utilizing an expansive list of search terms and extending beyond peer-reviewed literature and into gray literature. The search strategy allowed for characterization of systems approaches used in current practice and how they may be applied to enhance the governance and delivery of public health services. Key findings included: (1) very few articles (of the numerous citations) met our screening and eligibility criteria, (2) numerous different systems approaches were identified but not well-covered, and (3) retained articles did not represent a depth of applications for public health governance or service delivery. Each of these findings were somewhat unexpected, as modern organizational and systems theories have gained increasing traction since the beginning of the 20th century as leading, if not prevailing, theories across sectors. The author and members of the research team had expected to find articles which documented how specific systems approaches had been used to address problems associated with how public health systems were governed or services delivered, such as to enhance the impact of services through public-public or public-private partnerships.

The first unexpected finding was that so few articles were obtained that met our criteria, though our search strategy was quite broad and the initial pool of citations large; a larger catchment of citations and retained articles were expected for how decision-makers may have applied systems methodologies to public health governance or delivery. How services are governed and delivered are critical factors for the efficiency and effectiveness of delivery and represent important factors when determining resource allocation or collaborations. Like this study—though having a different objective—Carey et al (2015) produced a systematic review that identified literature representing how systems methodologies were applied within public health. That review also identified low numbers of citations in multiple categories of analysis but illustrated how articles could be identified. The finding that few relevant citations were obtained, and few articles retained, may indicate that systems approaches are not yet a prevailing technique of policymakers and practitioners within public health. This finding appears to be consistent with conclusions from prior commentaries (Diez Roux, 2015; Luke & Stamatakis, 2012; Pasmore et al., 2018; Peters, 2014; Siemieniuch & Sinclair, 2014; Silva et al., 2018), reviews (Carey et al., 2015; Ghaffarzadegan et al., 2010; Seidel, 2016), and studies (Diez Roux, 2011; Ip et al., 2013; Patorniti et al., 2017).

The second unanticipated finding was the number and variety of unique systems approaches identified from the review (Figure 2). Articles retained from the full-text review described numerous different systems approaches, though overall each approach received scant coverage with most approaches only being present within a single article. Among approaches, complex systems methods for both thinking in systems and analyzing continuously adaptive systems were most prominent among discourse, followed by common simulation methods (ABM, NA, SDM) with Luke and Stamatakis (2012) and Burke et al (2015) offering detailed discussions on public health applications for those simulation models. Though identification of common techniques was anticipated, novel models such as the "nexus model" and "Levins model" and unique applications of techniques from other disciplines such as the Malcolm Baldridge Framework applied to service systems were unknown techniques for these sorts of public health applications. Based on a scarcity of evidence, the author and other research members found that discourse related to use of systems approaches in designing or enhancing the governance structures or service delivery mechanisms in public health have only been partially addressed by available reviews, particularly regarding design or enhancement the delivery of services. The practice community has had some activity in this area, such as efforts to study the impacts of cross-jurisdictional or cross-sectoral sharing which suggests that certain system designs have the potential to enhance efficiency or effectiveness of services (Center for Sharing Public Health Services, 2018).

A final unanticipated finding was that the identified systems approaches were distributed unevenly across governance functions, were less explicitly described for delivery of services, and often allowed for a non-specific or broad application. Specifically, the more obvious finding to emerge from our review was the lack of volume and variety in literature for how systems approaches may design or enhance the governance structures or service delivery mechanisms in public health. The author and members of the research team initially believed it likely that decision-makers may rely upon systems science when designing or improving how public health systems may be governed or services delivered. Many examples of systems science techniques exist for program evaluation and purely technical applications such as software design or disease modeling (e.g., system dynamics or agent-based modeling), but there are seemingly few systems approaches used in the design of service systems such as public health. Authors of the extant materials suggested this may be, in part, due to the conceptual difficulty in methodological design (e.g., parameterization) and need for sufficient scientific rigor in coordinating non-traditional approaches (Diez Roux, 2015; Hassmiller Lich et al., 2017; Luke & Stamatakis, 2012; Purshouse et al., 2018; White, 2016). Each potential challenge may impede design or enhancement of public health systems to better address public health problems.

For context, the COVID-19 pandemic affected national and global service systems and infrastructure when it first gained a foothold in early 2020. The resulting crises led to critical stresses on both public and private sectors from which substantial economic and social losses coincided with loss of life and autonomy. Compounding those issues, governmental public health and healthcare systems faced critical shortages of personal protective equipment, testing supplies, life-saving equipment, and essential frontline workers which exposed the fragility of our human-made infrastructure (OECD, 2020). A substantial portion of the losses may have been avoided had those systems been afforded the benefits of resiliency that follows well-designed systems. The contention of the author and research team is that the expanded use of systems approaches when designing or changing internal organization or external delivery of services offers adaptability, reliability, and a robustness that allows the system to withstand and respond efficiently and effectively to threats (Brtis, 2020). This, in turn, may create opportunity for "discussion about the feasibility of alternate scenarios and…enables a richer conversation about the relationship between resources required and improvement in outcomes across scenarios" (Hassmiller Lich et al., 2017). Systems architecture holds promise to enhance both governance and service delivery. In fact, multi-level abstractions are presently observed in the public health enterprise from the level of societal governance, to organizations and their operations, to the agents of delivery systems (Lenartowicz, 2018; Madhavan et al., 2018; Purshouse et al., 2018). Contemporary examples of this are efforts to revitalize the 10 Essential Public Health Services, promote a modernized public health ("Public Health 3.0"), and increase adoption of a minimum package of public health services ("Foundational Public Health Services"), each as vehicles toward expanding systems approaches to transform public health practice.

Findings of this study may illustrate important gaps in knowledge for how systems approaches may be applied toward the governance of public health services or how they may be delivered. Though the author and research team had expected to find additional depth or variety of examples, the few retained articles represented strong examples of applications and the benefits of systems approaches for public health were clear in the findings. Select literature illustrates how systems science may be used for public health, such as how systems approaches used for design may improve the governance and delivery of services (Sims & Aboelata, 2019; Trochim et al., 2006). Further, systems approaches have been shown to strengthen cross-disciplinary collaboration and aid integration of disparate datasets (Bozeman, 2013; Diez Roux, 2011, 2015; Patorniti et al., 2017; Young et al., 2010). A handful of commentary articles have suggested the potential benefits of using systems approach for design of service systems like public health systems (Bar-Yam, 2006; Bauer, 2009; Diez Roux, 2011, 2015; Madhavan et al., 2018; Merrill et al., 2008). Design approaches may also be paired with other approaches such as constrained optimization, complex adaptive systems, or systems of systems methodologies to create a holistic systems architecture to investigate and design both governance (e.g., architectural perspectives) and service delivery (e.g., emergence of behaviors and influences of architecture) (Madhavan et al., 2018).

Limitations

There are several limitations to be highlighted for the study. First, common risks and limitations of reviews were present, such as potential for selection bias and bias toward published or positive results. To reduce this bias, the research team independently reviewed documents and did not exclude gray literature. A second limitation is that the methodology and key words may have been structured in a way that biased the results toward academic studies of concepts and away from documentation of practice-based efforts. Therefore, the finding that there was minimal literature about systems approaches applied to public health governance or service delivery may be more a function of the study design and selection criteria used, rather than a true finding. A final limitation is the extent to which findings may be generalized. The decidedly broad definition of 'systems approach' used in this review was reflective of the variation in definition across disciplines and may have traded specificity for sensitivity. Consequently, the set of approaches discussed in this study may expand beyond those considered in the conservative definition of systems approach but may also have overlooked relevant studies that used different terminology to describe similar approaches.

Conclusions

In this scoping review, the author and research team synthesized a broad range of studies which describe the utility and application of different systems approaches to benefit service systems. While not a panacea to infrastructure problems within society, when paired with scientific rigor, systems approaches may shed new light onto prevailing issues and lead to discovery of processes and associations not previously considered. An important finding of our review was discovering how few scientific studies have investigated the use of systems approaches in designing public health systems, let alone public policy or the relationships between governance, service delivery, and system performance. Further analytical studies are necessary to identify relevant design factors and determine their associations to system performance. Though public health has begun to take notice of the potential for broader applications, the author and research team (and prior investigators) contend that additional prioritization, academic training, and consensus on application of systems approaches is needed by public health leaders and practitioners to transform public health practice. Implications from the present study are that there may be a need for more demonstrations of systems methodologies in design or enhancement of public health governance or service delivery; at least, more documented demonstrations. Decision-makers should consider available methodologies, such as those described in this study, when seeking to create or improve public health systems.

While a wide variety of systems approaches were identified through the scoping review, none appeared appropriate for empirical investigation of the structural characteristics (including STS, CAS, Baldridge Framework). Therefore, it was determined that it may be best to first categorize local public health systems according to structural characteristics (e.g., governance, mechanisms of service delivery), then investigate the influence of covariates or roles of potential predictors. The following essays describe the development of such a typology (Chapter 3) and then ordinal regression against the categories identified in that typology to identify potential predictors for the typology (Chapter 4).

Chapter 3 – A Novel Typology of Local Health Departments with Latent Statuses Derived from the NACCHO Profile Study[2]

Introduction

The United States is served by a complex network of governmental public health agencies at local, state, and national levels, including Tribal authorities. Local public health systems very substantially across the nation, both across states and within them. This variation leads to different configurations of direction and control for agencies ("governance"), the roles of agents and partnerships involved in producing services ("service delivery"), and the mixtures of services offered by those agencies ("differentiation"); this, in turn, leads to differential population health outcomes for populations served (Institute of Medicine, 1988; Mays et al., 2016; Scutchfield et al., 2009; Timsina, 2017). There is a strong likelihood that such variation in practice and outcomes across the many different local public health systems may be derived from the organization and configuration of such systems through observed and unobserved factors.

Each public health system is a system like any other, according to rules that support the operation and regulation for the public's health. These systems are fraught with complex relationships and structures and inherent uncertainty due to human nature, including social, economic, environmental biological, and behavioral factors (Vidyanti, 2016). Public health systems also interact within and between public and private sectors, allowing for a number of shared objectives and opportunities to implement collaborative service delivery models that make deriving systems typologies challenging. A prior study by Mays et al. (2010) found seven

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[2] This paper is currently in the preparation process for publication in the Journal of Public Health Management and Practice. Citation: Orr, J. M. (2024). *A Novel Typology of Local Health Departments with Latent Statuses Derived from the NACCHO Profile Study*. Manuscript in preparation.

distinct typology configurations for local public health systems (see **Table 3**). Configurations were grouped within three tiers according to activities offered by the local public health system ("differentiation"), dependence and interdependency dynamics between partner organizations within that system ("integration"), and concentration of governance ("centrality"). The typology configurations resulted from a hierarchical clustering analysis of data obtained through the National Longitudinal Survey of Public Health Systems (NALSYS) that aims to classify structural characteristics of local public health delivery systems and their variation over time (Mays & Scutchfield, 2020; Mays et al., 2010). The study suggested that each typology configuration may influence the operations and outcomes of public health service delivery (Mays et al., 2010).

Table 3. Typology Framework for Local Public Health Systems (via NALSYS)

Label	Description
Tier I: Highly Differentiated Systems (*comprehensive*) *Broad scope of activities performed with a variable number and range of organizations participating in service delivery and a variable distribution of public health responsibility.*	
Concentrated Comprehensive System	wide range of organizations involved with local public health agency providing majority of effort
Distributed Comprehensive System	wide range of organizations involved and activity distributed among organizations
Independent Comprehensive System	narrow range of organizations involved with local public health agency providing majority of effort
Tier II: Moderately Differentiated Systems (*conventional*) *Moderate scope of activities performed with a moderate number and range of organizations participating in service delivery and a variable distribution of public health responsibility.*	
Concentrated Conventional System	local public health agency provides majority of effort (*highly transitory system*)
Distributed Conventional System	activity distributed among organizations (*most prevalent configuration*)
Tier III: Limited-Differentiation Systems (*limited*) *Narrow scope of activities performed with a variable number and range of organizations participating in service delivery and a variable distribution of public health responsibility.*	
Concentrated Limited System	limited range of organizations involved and local public health agency provides majority of effort
Distributed Limited System	moderate range of organizations involved with activity distributed among organizations

Source: Summary of typology provided by Mays et al. 2010

The approach by Mays et al. was inspiring: how may local public health systems be empirically classified and compared to identify the strengths and weaknesses inherent within the 'design' of those systems? Though NALSYS was designed with the intention of assessing the structural characteristics of local public health systems (Mays & Scutchfield, 2020), another longitudinal survey assesses similar characteristics but with a substantially larger periodic sampling: the National Association of County and City Health Officials' (NACCHO) National Profile of Local Health Departments (Profile) study (Inter-university Consortium for Political and Social Research, 2024). The NACCHO Profile studies are the most robust assessment of local public health in the United States, with each survey administration resulting in nationally representative datasets. These data offer an alternative data foundation for typological assessment based on data reported by local health departments (LHDs). Similarly, latent transition analysis (LTA)—a longitudinal extension of latent class analysis (LCA) that can estimate probabilities of transition between latent statuses—is a reasonable alternative approach to analyzing the largely categorical data offered by the Profile study.

For this study, a unique research question was devised in order to guide the development of a typology of local public health systems and investigation of resultant classifications: *How can latent transition analysis be used to classify local health departments into distinct statuses based on governance, centrality, colocation, and integration, and what are the transition probabilities between these statuses over time?* The primary objective of this study is to apply LTA methods to investigate the classification of local public health systems across multiple time points, classifying Profile study respondents (LHDs) into distinct statuses based on responses to observed variables. The resultant latent statuses for local health department respondents may offer a means of meaningful comparison and opportunity to examine the transition probabilities between these statuses over time.

Methods

Study Design and Sample

NACCHO surveys all LHDs in the United States periodically—survey administrations occur approximately every three years—and data from the 2013, 2016, and 2019 Profile study administrations were used.[3] Overall response rates for the studies in those years were 79% in 2013, 76% in 2016, and 61% in 2019.

Measures

Many variables present within the Profile study questionnaire were considered, aiming for alignment with the Mays et al. (2010) measures. The Profile survey includes items for key structural aspects of local public health systems related to governance and service delivery. The following four variables were selected as measures for the LTA as representing latent structural features of local public health systems:

- demographic item for LHD governance categorization ("*governance*," labeled 'c0govcat' by NACCHO) with options of 'unit of state government,' 'unit of local government,' and 'unit governed by both state and local authorities;'
- demographic item for LHD jurisdiction classification ("*centrality*," labeled 'c0jurisdiction' by NACCHO) with options of 'city,' 'county,' 'city-county,' 'multi-city,' and 'multi-county;'

[3] Data from the 2022 NACCHO Profile study administration were not made available until June 2024 and could not be included in the present analysis.

- response to whether LHD was part of a combined health and human services agency ("*colocation*," designated 'c2q501' by NACCHO) with response options of 'Yes,' "No', 'Do not know;'
- response to whether the LHD had services or resources sharing arrangements with other LHDs and the form of arrangement ("*integration*," designated as matrix variable 'm8q*^' by NACCHO with * = 401/402/403/601/602 and ^ = a/b/c) with response options consolidated to 'shared [functions],' '[formal] agreement,' 'informal [agreement],' and 'none.'

Lists of variables and descriptions are available in **Appendix F –Descriptions of Key Variables**.

Latent Statuses and Transition Analysis

Data were thoroughly cleaned to arrive at a dataset that included respondents with adequate data availability and key study variables. Respondents with incomplete surveys or substantial missingness were removed from the dataset. Minimal imputation and recoding were performed, however, more than 120 respondents' governance classifications were recoded where clearly misclassified (e.g., health department representing city and county governance was recoded as such).

An LTA model specification approach, using the PROC LTA SAS statistical package (*PROC LCA & PROC LTA*, 2015; *SAS Software*, 2024), was conducted to examine emergent typologies among LHDs based on the categorical variables for governance, centrality, colocation, and integration (see **Appendix G –SAS Programs and Procedural Syntax** for LTA syntax and programming). Data availability for respondents across the three study years (2013, 2016, 2019) allowed for testing across three time points. Key parameters were the number of latent statuses and number of time periods.

The model specification approach was iterative, involving repeated refinements and adjustments to the model parameters and seeds (without covariates) to achieve a robust and stable initial model. Latent statuses may best be determined through assessment of statistical fit and practical implications (Collins & Lanza, 2009; Lanza & Rhoades, 2013; Nylund et al., 2007). Statistical fit was assessed through evaluation of fit parameters: Akaike Information Criterion (AIC), the Schwarz Bayesian Information Criterion (BIC), deviance statistic (G^2), and degrees of freedom. Adequate statistical fit was determined by lowest BIC then lowest AIC (i.e., BIC & AIC closer to zero but non-negative) with G^2 and degrees of freedom being positive (Collins & Lanza, 2009). Robustness or practical fit of the latent statuses was assessed both by evaluating the item response probabilities (RHO parameters) in addition to visual inspection of item assignment to latent statuses; through a model may have sufficient statistical fit, it should also represent a feasible or practical outcome (Collins & Lanza, 2009; Lanza & Rhoades, 2013). Once a base model with adequate statistical and practical fit was identified, each latent status was descriptively labeled according to item response categories associated with highest inclusion probabilities.

Multinomial Logistic Regression with Covariates

Next, covariates were introduced to examine impacts on latent statuses (i.e., predictive nature) and transitions between statuses across time periods. Several covariates were identified or derived from the existing NACCHO Profile dataset that could serve as predictors for the latent statuses, representing services delivered by local public health systems and in which ways: a standardized variable for population served by the LHD (“population”), a categorical variable representing the presence of few to many services (“differentiation”), a categorical variable representing the mixture of services from primarily clinical to primarily population-based ("service mix"), a categorical variable representing presence of cross-sectoral sharing arrangements from limited to extensive ("extent of sharing"), and a categorical variable representing the strength of those arrangements ("integration"). Lists of variables and descriptions are available in **Appendix F –Descriptions of Key Variables**. Multinomial logistic regression incorporated in Proc LTA was used to evaluate predictors of membership in latent statuses over time.

Results

The core NACCHO dataset included approximately 2,453–2,533 unique LHDs per Profile study year (see **Table 4**). Following cleaning activities, the core NACCHO dataset included approximately 1,496–1,998 unique LHDs per Profile study year. A further narrowing of the dataset through restructuring the dataset for LTA resulted in incorporated approximately 1,417–1,790 LHDs per Profile study year; this involved removal of greater than 200 LHDs missing key variables across 2016–2019 time points. Finally, the model including covariates incorporated approximately 330–460 LHDs.

Table 4. Summary of LHDs Present at Each Analytic Step (by Profile study year)

Analytic Step	2013 Profile	2016 Profile	2019 Profile
Pre-Modeling			
Initial Unique LHDs	2,532	2,533	2,453
LHDs Present After Cleaning	1,998	1,929	1,496
Latent Transition Analysis			
LHDs Included in Base Model	*	1,790	1,417
LHDs Included in Covariate Model	*	457	334

** Base Model and Covariate Model only included 2016 and 2019 time points.*

Initial Model Specification

Correlation tests were performed for model variables at each time point. Some correlation was noted between 2016 governance and centrality variables. Though statistically significant, the correlation coefficients were small (-0.12) which did not indicate high correlation; no changes to model variables were made. Data from correlation tests are available in **Appendix H –Detailed Results for Model Specification**.

Next, the iterative model specification approach looped through combinations of the following PROC LTA parameters:

- Latent Statuses (“NSTATUS”): from 04 to 12 status selections;
- Time Points (“NTIMES”): from 2 [2016, 2019] to 3 [2013, 2016, 2019] periods; and
- Random starting parameters (“SEED”): 123456, 654321 (arbitrary seed values).

Resultant model parameters for assessment of statistical fit were organized into a comparison table by Run ID and reviewed for best fit (see **Table 5**). Model fit was prioritized according to lowest BIC and AIC—prioritizing BIC with respect to model complexity—then lowest G^2 (i.e., lower likelihood-ratio chi-square statistic between observed and expected frequencies), maximized value of logarithm of the likelihood function (-2 Log L), then highest maximum Delta (i.e., higher probability of items included within given status). The model representing the best statistical fit was **Run ID 06_2_654321**: *a six-status, two-time model*.

Table 5. Statistical Fit Parameters for All Model Specification Iterations

Run ID*	G^2	AIC	BIC	Degrees of Freedom	Maximum Delta
04_2_123456	1662	1852	2380	14304	0.5202
04_2_654321	1882	2072	2601	14304	0.5492
04_3_123456	3758	4052	4869	1727852	0.5182
04_3_654321	3668	3962	4780	1727852	0.5182
05_2_123456	1462	1710	2400	14275	0.5202
05_2_654321	1294	1542	2232	14275	0.5204
05_3_123456	2893	3281	4360	1727805	0.5182
05_3_654321	2732	3120	4198	1727805	0.5182
06_2_123456	1286	1596	2458	14244	0.4382
06_2_654321	1085	1395	2257	14244	0.5202
06_3_123456	2271	2761	4123	1727754	0.4572
06_3_654321	3966	4456	5819	1727754	0.2759
07_2_123456	1213	1589	2634	14211	0.4383
07_2_654321	1236	1612	2658	14211	0.4224

Run ID*	G^2	AIC	BIC	Degrees of Freedom	Maximum Delta
07_3_123456	2636	3236	4904	1727699	0.4114
07_3_654321	3303	3903	5571	1727699	0.3731
08_2_123456	1051	1497	2737	14176	0.3846
08_2_654321	1303	1749	2989	14176	0.2987
08_3_123456	2626	3344	5340	1727640	0.3748
08_3_654321	3336	4054	6050	1727640	0.2849
09_2_123456	837	1357	2803	14139	0.3602
09_2_654321	908	1428	2873	14139	0.2987
09_3_123456	2091	2935	5282	1727577	0.3573
09_3_654321	1927	2771	5118	1727577	0.3127
10_2_123456	833	1431	3093	14100	0.2964
10_2_654321	709	1307	2970	14100	0.2790
10_3_123456	2083	3061	5780	1727510	0.2626
10_3_654321	1837	2815	5534	1727510	0.3069
11_2_123456	727	1407	3298	14059	0.4059
11_2_654321	479	1159	3049	14059	0.2938
11_3_123456	1350	2470	5584	1727439	0.3091
11_3_654321	2057	3177	6291	1727439	0.3329
12_2_123456	682	1448	3578	14016	0.2213
12_2_654321	791	1557	3687	14016	0.2984
12_3_123456	1333	2603	6134	1727364	0.3573
12_3_654321	2350	3620	7151	1727364	0.2382

* *Run IDs are constructed by [NSTATUS]_[NTIMES]_[SEED].*
Parameters include: Deviance statistic (G^2), Akaike Information Criterion (AIC), Schwarz Bayesian Information Criterion (BIC), degrees of freedom, and maximum Delta (i.e., likelihood of inclusion in status)

Only models of two time points (2016, 2019) offered adequate fit and were considered. Prior exploratory analyses found that many alternate model specifications including 2013 data failed to converge or otherwise led to misspecifications or errors (e.g., negative G^2, instability across seed values, substantial deviations of delta parameters). Similarly, only models with fewer than ten latent status selections were considered. Outputs for each of the runs representing two time points and 4–9 latent statuses were assessed for practical fit according to RHO parameters and visual inspection. Though several models included similar item assignment to latent statuses via RHO parameters, the *six-status, two-time model* was also the most practical.

Base Model Creation and Evaluation

The selected six-status, two-time model appeared to possess the best overall statistical fit (BIC = 2,257, AIC = 1,395, DoF = 14,244, G2 = 1,085, -2Log(L) = -5,347, max. Delta = 0.52). The AIC and BIC values were among the lowest afforded through model specification. Reasonable consistency was observed for model fit parameters and RHO parameters between SEED values, though some violations of difference thresholds were observed for some parameters (e.g., >5% for fit parameters, >10% for RHO parameters). Parameter outputs are available in **Appendix H –Detailed Results for Model Specification**.

The following configurations general configurations were emergent from the item response probabilities (see **Table 6**). The general structure of the latent statuses and distribution of LHDs appeared reasonable as a practical model for local public health systems.

Table 6. Emergent Statuses and Likelihood of Item Responses to be Present in Latent Status

Latent Status	Likelihood of Specific Item Responses to be Present in Latent Status
Status 1	• City LHDs (strong probability) • Locally governed LHDs (weak probability)*
Status 2	• County LHDs (weak probability)* • Shared state and local governance of LHD (strong probability) • Formal cross-jurisdictional sharing arrangements (weak probability)*
Status 3	• County LHDs (weak probability)* • Locally governed LHDs (weak probability)* • Formal cross-jurisdictional sharing arrangements (weak probability)*
Status 4	• County LHDs (weak probability)* • State-governed LHDs (strong probability)
Status 5	• City-county LHDs (weak probability) • Multi-city LHDs (moderate probability) • Locally governed LHDs (weak probability)* • Formal cross-jurisdictional sharing arrangements (weak probability)*
Status 6	• Multi-county LHDs (strong probability) • City-county LHDs (weak probability)
All Statuses	• Both presence and absence of colocation with health and human services agencies were equally distributed across statuses (i.e., equal probabilities).

	• Absence of cross-jurisdictional sharing arrangements, presence of informal arrangements, or presence of shared oversight of services across multiple jurisdictions were equally distributed across statuses (i.e., equal probabilities).

** Weak probability of being present in 2 or 3 latent statuses.*

There were 1,920 LHDs available for the LTA at either time point. Posterior probabilities output from the LTA were used to assign LHDs to latent statuses at different time points; the status associated with the highest probability was selected for each LHD (see **Table 7**). Only one of the specific categorical response items for any of the four variables were associated exclusively with any of the latent statuses, all others were present in multiple latent statuses. All 219 of the city-based LHDs were included in Status 1 in both time points, as well as 30 LHDs that represented other jurisdictional setups.

Table 7. Distribution of LHDs Across Latent Statuses of Base Model

Latent Status	2016 Cohort (N LHDs, %)		2019 Cohort (N LHDs, %)	
Status 1	249	*12.97%*	249	*12.97%*
Status 2	138	*7.19%*	138	*7.19%*
Status 3	997	*51.93%*	997	*51.93%*
Status 4	303	*15.78%*	303	*15.78%*
Status 5	145	*7.55%*	145	*7.55%*
Status 6	88	*4.58%*	88	*4.58%*
	1920		**1920**	

Though there were 1,920 LHDs available for the LTA at either time point, only 1,287 LHDs were represented in both 2016 and 2019 time points. However, there were some deviations in reported items for certain model variables from T1–T2 (count of LHDs that differed with percent of total): Governance (24 LHDs, 2%); Centrality (10 LHDs, 1%); Colocation (118 LHDs, 9%); and Integration (90 LHDs, 7%). Reflecting upon **Table 7**, these deviations did not appear substantial enough to result in a change in estimated latent status (i.e., TAU parameters were each 1.0 for Status 1 to Status 1, Status 2 to Status 2, etc.).

Modifications with and Evaluations of Covariates

Covariates were included for the 2016 and 2019 time points. However, model errors were produced when any covariates were included for the 2019 time point (“COVARIATE2). Covariates were only included for the 2016 time point. Correlation tests were performed for model covariates at the 2016 time point. Some correlation was noted between different combinations of parameters (with respective correlation coefficients):

- *minimal correlation*: population and differentiation predictors (0.13), population and service mix predictors (0.13);
- *minor correlation*: extent of sharing and service mix (0.24), extent of sharing and differentiation (0.31); and
- *moderate correlation:* differentiation and service mix (0.68).

Though statistically significant, the correlation coefficients were all below a practical threshold (0.80); no changes to model covariates were made. Data from correlation tests are available in **Appendix I –Detailed Results for Covariate Analysis**. Additionally, an iterative approach was taken to determine if a “BETA PRIOR” parameter—stabilization factor— would be needed. Multiple successive iterations of the base model with covariates using different BETA PRIOR values (1 / 5 / 10 / 20) found that best stability was afforded with BETA PRIOR = 1.

Impact of Covariates on Base Model

Introducing covariates to the six-status, two-time model led to similar parameter values and outputs for the model; BIC, AIC, DoF, and G^2 are not output with covariates present, however other parameters could be assessed (-2Log(L) = -1,591, max. Delta = 0.42). The following changes were observed with respect to statuses and related item response probabilities (in comparison to **Table 6**):

- County LHDs were found to have a weak probability to also be within Status 6;
- LHDs with formal cross-jurisdictional sharing arrangements were found to be more distributed with weak probabilities to be present in all but Status 5;
- LHDs collocated with health and human services agencies were found to have a high probability to be present in Status 5;
- Multi-county LHDs were found to have a high probability to be present in Status 5, instead of Status 6;
- LHDs serving as units of local government were found to have a moderate probability of being in Status 5 but a high probability of being in Status 4; and
- LHDs serving as units of state government were found to have lower probability of being in Status 5 but a high probability of being in Status 4.

There were 457 LHDs available for the LTA at either time point once covariates were introduced; the lower number of observations was still sufficient for use with Proc LTA. Posterior probabilities output from the LTA were used to assign LHDs to latent statuses at different time points; the status associated with the highest probability was selected for each LHD. None of the specific categorical response items for any of the four latent variables nor the four covariates were associated exclusively with any of the latent statuses. See **Table 8** for the distribution of LHDs across statuses. There were some proportional changes in LHD assignment to specific latent statuses following introduction of covariates. Most notably, Status 3 held the largest proportion of LHDs in the base model, but Status 4 now includes the largest proportion. Status 6 also increased in proportion of LHDs included.

Table 8. Distribution of LHDs Across Latent Statuses of Base Model with Covariates

Latent Status	2016 Cohort (N LHDs, %)		2019 Cohort (N LHDs, %)	
Status 1	62	*13.57%*	62	*13.57%*
Status 2	47	*10.28%*	49	*10.72%*
Status 3	41	*8.97%*	55	*12.04%*
Status 4	190	*41.58%*	176	*38.51%*
Status 5	53	*11.60%*	51	*11.16%*
Status 6	64	*14.00%*	64	*14.00%*
	457		**457**	

There were some deviations in reported items for certain model variables from T1–T2 (count of LHDs that differed with percent of total): Governance (6 LHDs, 1%); Centrality (5 LHDs, 1%); Colocation (30 LHDs, 7%); and Integration (56 LHDs, 12%). Reflecting upon **Table 8**, these deviations, or covariate interactions, did appear substantial enough to result in a change in estimated latent status, which was also verified through changes to TAU parameters. Same-status transition probabilities dropped for several TAU parameters: Status 3 to Status 3 (0.94), Status 4 to Status 4 (0.90), and Status 5 to Status 5 (0.91). Cross-status transition probabilities raised a few points for multiple items, most substantially Status 4 to Status 3 (0.10). There were a total of 20 LHD transitions among the 457 LHDs:

- Status transition from 4 (T1) to 3 (T2) = 15,
- Status transition from 3 (T1) to 2 (T2) = 1,
- Status transition from 5 (T1) to 2 (T2) = 1,
- Status transition from 5 (T1) to 4 (T2) = 1,
- Status transition from 5 (T1) to 3 (T2) = 1, and
- Status transition from 3 (T1) to 5 (T2) = 1.

The absence of statistical fit parameter outputs from the Proc LTA made it challenging to assess statistical fit of the underlying model. However, introduction of covariates for 2016 did not lead to model misspecification.

Discussion

The latent variable analysis performed in this study had two primary goals: a) maximization of heterogeneity between latent statuses to arrive at distinct groupings of LHDs, and b) maximization of homogeneity within each latent status such that LHDs included within each latent status are as similar as possible (Roesch et al., 2010). Creating a typology of governmental public health systems is complicated, largely due to the ubiquity of system structures and operations both across states and within states. An LTA approach is beneficial toward identifying key factors that may not be directly observed but may be inferred based on findings from analyses (Roesch et al., 2010).

Intents of the present study were to both replicate the methods performed by Mays & Scutchfields' NALSYS study (2020) and to extend the typologies described in the introduction to the additional variables available from the NACCHO Profile study and leverage the additional respondents to the periodic Profile study. The questions of both longitudinal studies align in some aspects of governance, service delivery, and services delivered, which makes comparison an obvious interest. While response rates were somewhat similar across the NALSYS and NACCHO Profile studies, the periodic NALSYS sample frames were restricted to local public health systems that served at least 100,000 persons—approximately 500 local public health systems—whereas the periodic NACCHO Profile survey sample frames represented nearly all local public health agencies—approximately 2,500 of the approximately 3,000 local public health agencies (Inter-university Consortium for Political and Social Research, 2024; Mays &

Scutchfield, 2020). Therefore, the periodic NALSYS survey (with ~60% response rate) relates to approximately 300 local public health systems on average whereas the periodic Profile study (with ~75% response rate) relates to approximately 1,800 local public health agencies. Though, with higher typical response rates and sample frames, the NACCHO Profile study also suffers from similar data quality issues to that of the NALSYS study and some key variables of interest, such as partnerships and collaboration and cross-jurisdictional sharing questions, are only available in modules sent to statistical samples of local health departments.

The base model appeared to have excellent statistical fit, representing adequate responsiveness to model complexity and robustness parameters. The model also appeared to have reasonable practical fit (i.e., the model made literal sense), as described in **Table 6**. Many aspects of the latent status characteristics made excellent sense, such as how multi-jurisdictional health departments tended to be grouped together (e.g., multi-county and city-county LHDs found in Status 6, city-city and city-county LHDs found in Status 5) whereas LHDs representing a single geopolitical jurisdiction were grouped separately (e.g., city LHDs found exclusively in Status 1, county LHDs found in Statuses 2–4); these findings were observed in **Table 7** (*base model*) and **Table 8** (*model with covariates*). While the hope was that status transitions would be observed and characterized, it also made sense that transitions would be infrequent, given how rare events such as mergers and consolidations of LHDs or drastic changes in services may be; state-local governance dynamics have largely stayed the same for more than a decade. Lastly, though Mays et al. considered public health service mix (differentiation) as a factor for their typology, it seemed that the activities delivered by local health departments may be emergent from the design of local public health systems (i.e., predictive), rather than an underlying grouping variable (i.e., latent).

An unexpected finding was that, while the model appeared to be statistically sound and made some literal sense when considering variable categories present within a given status, the overall assignment of variable categories across statuses may have practical limitations. The perception of such practical limitations may be related to measurement variance hidden within the existing latent statuses, potentially discoverable by recognizing that certain variable categories differed between statuses emergent at different time points and may bias results (e.g., city-county health departments in S1 at T1 but S2 at T2). Also unexpected was the instability observed when data from Profile administrations prior to the 2016 year were present. At the outset, the author's intent was to perform a longitudinal analysis back to the 2010 Profile study (or further back toward the initial study years). However, due to the fact that many priority variables were either included in modules sent only to statistical samples or exhibited trend breaking as well as lower multi-year consistency by the same respondent, model stability was unable to be achieved.

Model stability was confirmed by consistent statistical parameters across seeds. Robustness was largely demonstrated, though some deviations between RHO parameters raise questions for overall robustness. Comparison of the selected model (best fit) and alternate models (lesser fit) identified very similar patterns of association. For example, a 3-status 2-time model found, for both time points, more than three quarters of categorical responses were found within the same contained statuses (e.g., non-colocated city and multi-county health departments with no reported cross-jurisdictional sharing within the same contained status). This illustrates the power of certain factors as driving forces for statuses without strong evidence of collinearity or correlation between those factors. Notably, introduction of covariates significantly impacted not only the data infrastructure of the model but also latent transitions, aligning with theoretical expectations that the introduction of additional influences to the model would likely change its performance.

Strengths and Limitations

There are a variety of notable data limitations associated with the NACCHO Profile questionnaires and the self-reported nature of survey data. While unique and comprehensive for local public health, the Profile study data has inherent limitations related to a) participant interpretations and depth of descriptions for concepts or items (e.g., no definitions are offered for each of the programs and services items); b) data quality and completeness of surveys (e.g., some questions skipped or missingness imputed); and c) extent of practical interpretations of data (e.g., some data elements may indicate presence or absence of services delivered but not their scope or scale) (National Association of County and City Health Officials, 2020). With respect to the present analysis, key limitations affecting model specification included data quality issues and trend breaks across study years (substantial for some priority variables) that prevented multi-year analysis across the longitudinal study; adequate model specification required focus on 2016 and 2019 survey years and a narrow set of latent variables that afforded sufficient data. However, with respect to local public health data, the NACCHO Profile study represents the "largest, most reliable data source on LHDs" (Inter-university Consortium for Political and Social Research, 2024). These data are routinely used for analyses of local public health systems.

While latent class and latent transition analyses are powerful statistical techniques that may identify hidden (latent) factors underlying data, some key limitations exist. These analyses assume independence of variables within each latent class (identified through correlation and collinearity tests) and class invariance across subpopulations. There also exists a subjective nature inherent in class or status selection with implications for both complexity and overfitting or underfitting with respect to that choice. For latent transition analyses, there also exist assumptions such as first-order Markov dynamics that may misrepresent underlying data or transitions.

There exists some potential to join in data from NACCHO's periodic Forces of Change study that assesses changes in local public health capacity and activities (offered in years between NACCHO Profile administrations), though, the more restrictive sample may limit observations available for latent status analyses. Future research should explore the accuracy and reliability of the model's selected variables for such latent analyses, with special attention toward multi-year stability and issues underlying challenges with using 2013 data. Additional exploration should be conducted to identify other relevant model parameters, covariates, and datasets.

Conclusions

The present study successfully applied latent variable analysis to create a typology of governmental public health systems. This approach aimed to maximize heterogeneity between latent statuses, resulting in distinct groupings of LHDs, and homogeneity within each latent status, ensuring similarity among LHDs in the same group. The use of LTA proved beneficial in identifying key, unobserved factors that influence these groupings. The characteristics of the latent statuses made logical sense, with multi-jurisdictional LHDs grouped together and single-jurisdiction LHDs grouped separately. Measurement variance within latent statuses, particularly following introduction of covariates, suggested potential biases, particularly with data from earlier Profile administrations, which impacted model stability and the longitudinal analysis. This highlights the importance of considering external influences in latent variable analyses. The NACCHO Profile study data, while comprehensive, had inherent limitations related to participant interpretations, data quality, and the practical interpretation of survey items, which stymied multi-year analysis. This study provides valuable insights into the structure and dynamics of governmental public health systems. While there are limitations, the use of LTA has highlighted key factors and provided a foundation for future research to build upon.

The following essay will further investigate the typology devised for the base model in the present study and will apply ordinal regression to the latent statuses to identify potential predictors for the typology. Identification of predictors may offer actionable insights for public health policy or strategic planning and may highlight areas for future research or intervention for local public health systems.

Chapter 4 – Ordinal Regression Analysis of Local Health Departments' Latent Status Across Community Health Outcomes: Insights from the NACCHO Profile Study[4]

Introduction

The nation is represented by a vast number of local health departments (LHDs) that provide necessary policy development and enforcement activities. LHDs play a critical role in public health systems, providing essential services that directly impact community health outcomes (Erwin, 2008; Institute of Medicine, 2012). Understanding the factors that influence the configuration and effectiveness of LHDs is crucial for enhancing public health strategies and policies. Previous studies have highlighted the complexity of LHD structures and operations, which vary significantly across different regions and over time. A prior study suggested that local public health systems may align with typology frameworks and each typology configuration may influence the operations and outcomes of public health service delivery (Mays et al., 2010). In their study, differential population health outcomes were observed for different configurations. For example, their "comprehensive systems" tier included local public health systems that were highly integrated and was found to have had the highest average perceived effectiveness, while the "conventional systems" tier had the lowest average perceived effectiveness (Mays et al., 2010). Studies by Mays et al and others suggest that optimal structures for local public health systems may depend upon local circumstances facilitating the ability and willingness of other organizations to provide public health services (Bekemeier et al., 2014).

[4] This paper is currently in the preparation process for publication in the Journal of Public Health Management and Practice. Citation: Orr, J. M. (2024). *Ordinal Regression Analysis of Local Health Departments' Latent Status Across Community Health Outcomes: Insights from the NACCHO Profile Study*. Manuscript in preparation.

For this study, a unique research question was devised to guide further investigation of the typology described in the prior essay: *How do various community health outcomes influence the latent statuses of local health departments, as identified through latent transition analysis, and what are the significant predictors of these latent statuses through ordinal regression?* The primary objective of this study is to investigate the relationship between various community health outcomes and the latent statuses of LHDs. These latent statuses, derived from a latent transition analysis (LTA), represent distinct configurations of LHDs that reflect their operational and structural characteristics. By examining how different community health indicators influence these latent statuses, key predictors may be identified that could inform public health policy and resource allocation. A strong source of data for community health outcomes with respect to local public health systems are through the County Health Rankings & Roadmaps ("CHR&R") project, which aggregates measures across a wide range of factors related to how long and how well communities live (*County Health Rankings & Roadmaps 2024*, 2024).

To achieve this objective, a cumulative logit model was considered as a means to assess ordinal outcomes. This model assumes that the relationship between predictors and the outcome is consistent across all thresholds of the ordinal variable, making it a popular choice for such analyses (*8.4 - The Proportional-Odds Cumulative Logit Model*, 2024). An alternative approach was considered through a generalized logit model. Unlike the cumulative logit model, the generalized logit model does not assume proportional odds, allowing the relationship between predictors and the outcome to vary across different levels of the ordinal dependent variable. This flexibility is essential given the complexity and variability of the LHD configurations in the data.

This study contributes to the existing literature by using advanced ordinal regression techniques to explore the determinants of LHD latent statuses. By identifying significant predictors of these statuses, the findings can inform public health practitioners and policymakers about critical factors that influence the effectiveness and configuration of LHDs. This knowledge is vital for designing interventions and policies aimed at improving public health systems and, ultimately, community health outcomes.

Methods

The 2019 NACCHO Profile study year was selected as the most recently available data on local public health systems. The core NACCHO dataset included approximately 2,453 unique LHDs for the 2019 Profile study year. Restructuring the dataset for latent transition analysis resulted in incorporated approximately 1,417 LHDs for the 2019 Profile study year. An LTA was performed with those data for a selected six-status, two-time model, which appeared to possess the best overall statistical fit (Schwarz Bayesian Information Criterion [BIC] = 2,257, Akaike Information Criterion [AIC]= 1,395, DoF = 14,244, deviance statistic [G^2] = 1,085, -2Log(L) = -5,347, max. Delta = 0.52). The probabilities output dataset per each unique LHD—with respective latent statuses for the 2019 Profile year—was used for the present analysis. Additional details on the specification of that latent status model and characterization of outputs from the base model are available in the prior essay (Chapter 3). Lists of variables and descriptions are available in **Appendix F –Descriptions of Key Variables**.

This dataset was then joined with 2019 calendar year community health outcome data made available by the CHR&R project. Joins were made possible via connections between the NACCHO Profile respondent NACCHO IDs (unique IDs), Federal Information Processing Standards (FIPS) codes of those respective jurisdictions; CHR&R data are available with jurisdictional FIPS codes (*County Health Rankings & Roadmaps 2024*, 2024). CHR&R measures were used to assess how the different latent statuses ("typologies") may influence population health outcomes: *premature death* ("v001"), *poor or fair health* ("v002"), *poor physical health days* ("v036"), *low [infant] birthweight* ("v037"), *preventable hospital stays* ("v005")[5], *life expectancy* ("v147"), and *premature age-adjusted mortality* ("v127"). Variables were selected as key outcome measures used by the CHR&R; each variable was continuous. Lists of variables and descriptions are available in **Appendix F –Descriptions of Key Variables**.

The ordinal nature of the latent statuses impeded the use of linear regression, which leverages continuous dependent variables. Ordinal regression was selected as a powerful statistical method to analyze the independent variables against the latent status variable (ordinal). This allowed for the relationship between latent statuses and potential predictor variables to be modeled, including both continuous and categorical data. Additionally, it allows for the inclusion of multiple predictors that could control various factors simultaneously while allowing for collective impact by the set. A key assumption for this approach is that the relationship between the predictors and their odds of being in higher outcome categories may be consistent ("proportional odds assumption"). This assumption was tested within the analytic approach. In lieu of proportional odds assumption violation, a partial proportional odds model was generated to receive necessary flexibility to accurately model the data. To assess the significance of each predictor variable in the presence of others, a Type 3 Analysis of Effects was used and offered Wald Chi-Square statistics and p-values for each predictor to assess unique contributions. Odds ratio (OR) point estimates reflect associations (OR = 1 indicates no effect, OR > 1 indicates positive association, OR < 1 indicates negative association) and the 95% Wald confidence limits

[5] Preventable hospital stays is considered a "clinical care" measure by CHR&R but was included as an outcome for this analysis.

may be narrow (indicating precise estimates) or wide (indicating imprecise estimates); extreme odds ratios or extreme confidence limit ranges may indicate data scaling or quality issues, multicollinearity, etc. Findings from both cumulative logit models and proportional odds models are reported.

Results

Cumulative Logit Model

Posterior probability outputs from the latent transition analysis were joined to the CHR&R data using NACCHO ID and FIPS as unique identifiers. The combined dataset was then pared down to only the key LTA output variables for the 2019 NACCHO Profile study year—and only those LHDs—and the independent variables of interest.

A cumulative logit model was run with latent status as a dependent variable (ordinal regression). Response profiles for each status, including frequencies, are available in **Table 9**. Of note, 386 observations were deleted due to missing values. Fit parameters for the revised model—AIC, SC, and log likelihood (-2 Log L)—are provided for both the intercept-only model and the model with covariates (see **Table 10**). The model with covariates has a lower AIC (3450.205 vs. 3554.711), indicating a better fit when predictors are included. Note that the resultant fit parameters in both instances are larger than those afforded by the base model (described in Methods) and may indicate lesser fit than through the base model.

Table 9. Logistic Model Response Profile (Cumulative Logit)

Ordered Value	Latent Status	Total Frequency
1 (Status 1)	1	13
2 (Status 2)	2	138
3 (Status 3)	3	944
4 (Status 4)	4	300
5 (Status 5)	5	70

Ordered Value	Latent Status	Total Frequency
6 (Status 6)	6	69

Table 10. Latent Transition Analysis Model Fit Statistics via Cumulative Logit Model

Criterion	Intercept Only	Intercept and Covariates
AIC	3554.711	3450.205
SC	3581.389	3514.233
-2 Log L	3544.711	3426.205

Outputs from Tests Performed (Cumulative Logit)

The proportional odds assumption was tested. Findings from tests of the proportional odds assumption indicated that the chi-square value was 851.8760 with a p-value < 0.0001, indicating that the proportional odds assumption was violated. This is a significant issue as it suggests that the relationship between the predictors and the outcome is not consistent across all levels of the ordinal dependent variable. *A secondary analysis using a generalized logit model resulted from this finding.*

The global null hypothesis was also tested (BETA = 0), which included tests with respect to likelihood ratio, score, and Wald statistics. All three tests (Likelihood Ratio, Score, and Wald) had p-values < 0.0001, which indicated that the overall model was statistically significant. Similarly, analysis of maximum likelihood estimates found that all intercepts were significant, suggesting that the thresholds for the latent statuses were well-defined. Likelihood estimates did find that two of the independent variables were significant predictors: preventable hospital stays (v005, p = 0.0007) and life expectancy (v147, p = 0.0026) may be significant predictors of the latent status. The remaining independent variables were not significant predictors (i.e., p > 0.05). However, these findings may be inconsistent.

Estimations and Predictive Nature of the Cumulative Logit Model

There were some notable findings with respect to the potentially significant predictors noted above. For preventable hospital stays, the point estimate of 1.000, included within seemingly nonexistent confidence limits, would suggest minimal practical predictive potential, despite the aforementioned statistical significance. The life expectancy factor, however, included a point estimate of 1.227 within the 95% CI (1.074, 1.402), which indicates a positive association with respect to being in a particular latent status. Lastly, some overall estimated findings and relationships indicated both a strong model concordance (63.8%) and Somers' D (0.287)—quantification of scalar and vector properties of the relationship between latent status and independent variables—suggest a modest predictive power of the model. However, these findings may be inconsistent.

Detailed outputs for the cumulative logit model are available in **Appendix J –Detailed Results for Ordinal Regression of Latent Status**.

Proportional Odds Logit Model

Following violation of the proportional odds assumption, an alternative ordinal regression approach was pursued, utilizing a partial proportional odds logit model with the same initial dataset. The new generalized logit model was run with latent status as a dependent variable (ordinal regression); latent status 6 was used as the reference category. Response profiles for each status, including frequencies, were identical to that of the prior model and are available in **Table 9**. Of note, 386 observations were deleted due to missing values. Fit parameters for the revised model were similarly provided for both the intercept-only model and the model with covariates (see **Table 11**). The model with covariates has a lower AIC (2905.077 vs. 3554.711), indicating a better fit when predictors are included. Note that the resultant fit parameters in both instances are larger than those afforded by the base model (described in Methods) and may indicate lesser fit than through the base model, but lower than that of the prior cumulative logit model and may offer better fit.

Table 11. Latent Transition Analysis Model Fit Statistics via Generalized Logit Model

Criterion	Intercept Only	Intercept and Covariates
AIC	3554.711	2905.077
SC	3581.389	3118.502
-2 Log L	3544.711	2825.077

Outputs from Tests Performed (Generalized Logit)

The global null hypothesis was also tested (BETA = 0), which included tests with respect to likelihood ratio, score, and Wald statistics. All three tests (Likelihood Ratio, Score, and Wald) had *p*-values < 0.0001, which indicated that the overall model was statistically significant. The Type 3 Analysis of Effects indicated that several predictors had significant effects on the latent statuses of local health departments (LHDs). Specifically, premature death (Wald Chi-Square = 25.3719, p = 0.0001), poor or fair health (Wald Chi-Square = 12.1839, p = 0.0324), poor physical health days (Wald Chi-Square = 70.3210, p < 0.0001), low birthweight (Wald Chi-Square = 41.8042, p < 0.0001), preventable hospital stays (Wald Chi-Square = 55.6295, p < 0.0001), life expectancy (Wald Chi-Square = 34.2212, p < 0.0001), and premature age-adjusted mortality (Wald Chi-Square = 32.1128, p < 0.0001) were all statistically significant (see **Table 12**). However, analysis of maximum likelihood estimates found that many intercepts and some predictors were not significant, suggesting caution may be needed with respect to interpretation of certain parameters.

Table 12. Type 3 Analysis of Effects via the Generalized Logit

Effect	DF	Wald Chi-Square	Pr > ChiSq
Premature death (v001)	5	25.3719	0.0001

Effect	DF	Wald Chi-Square	Pr > ChiSq
Poor or fair health (v002)	5	12.1839	0.0324
Poor physical health days (v036)	5	70.3210	<.0001
Low [infant] birthweight (v037)	5	41.8042	<.0001
Preventable hospital stays (v005)	5	55.6295	<.0001
Life expectancy (v147)	5	34.2212	<.0001
Premature age-adjusted mortality (v127)	5	32.1128	<.0001

Estimations and Predictive Nature of the Generalized Logit Model

There were additional notable findings with respect to the odds ratio (OR) estimates within the context of prior generalized logit model findings (see **Table 13**). Some ORs were extreme (>999.999 or <0.001), which could indicate potential issues with the model's specification or data scaling. Additionally, some predictors presented with very wide confidence intervals suggesting instability in the estimates. For instance, the independent variable representing poor or fair health (v002) was found to have an OR >999.999 with exceptionally wide 95% CI (<0.001, >999.999) and the independent variable representing low birthweight also had a high OR of >999.999 with exceptionally wide 95% CI (9.588, >999.999). These findings may indicate multicollinearity or outliers and may also be a factor in the issues identified for the cumulative logit model.

Table 13. Odds Ratio Estimates via Generalized Logit

Effect	Latent Status	Point Estimate	95% Wald Confidence Limits	
Premature death (v001)	1	0.999	0.998	1.000
	2	1.000	1.000	1.001
	3	1.000	1.000	1.001
	4	1.000	0.999	1.000
	5	1.001	1.000	1.001
Poor or fair health (v002)	1	>999.999	<0.001	>999.999
	2	<0.001	<0.001	13.411

Effect	Latent Status	Point Estimate	95% Wald Confidence Limits	
	3	0.003	<0.001	>999.999
	4	<0.001	<0.001	0.281
	5	8.785	<0.001	>999.999
Poor physical health days (v036)	1	0.080	0.007	0.872
	2	5.634	2.041	15.554
	3	2.513	1.067	5.919
	4	19.523	7.413	51.418
	5	1.513	0.481	4.756
Low [infant] birthweight (v037)	1	>999.999	9.588	>999.999
	2	<0.001	<0.001	>999.999
	3	<0.001	<0.001	<0.001
	4	<0.001	<0.001	91.100
	5	<0.001	<0.001	<0.001
Preventable hospital stays (v005)	1	1.000	0.999	1.000
	2	1.000	1.000	1.000
	3	1.000	1.000	1.000
	4	1.000	1.000	1.000
	5	1.000	0.999	1.000
Life expectancy (v147)	1	1.110	0.484	2.545
	2	1.625	1.074	2.458
	3	0.843	0.574	1.236
	4	0.830	0.529	1.302
	5	0.762	0.454	1.279
Premature age-adjusted mortality (v127)	1	1.023	0.998	1.048
	2	1.003	0.988	1.018
	3	0.986	0.973	0.999
	4	1.004	0.990	1.018
	5	0.977	0.959	0.994

Detailed outputs for the generalized logit model are available in **Appendix J –Detailed Results for Ordinal Regression of Latent Status**.

Summary Findings for Community Health Outcomes

The generalized logit model identified several significant predictors of latent statuses among LHDs, revealing key insights into how community health outcomes impact the configuration and functioning of LHDs.

Table 14. Summary of Findings for Predictors

Effect	Finding
Premature death (v001)	Higher rates of premature death were associated with less favorable latent statuses.
Poor or fair health (v002)	Higher percentages of the population reporting poor or fair health were associated with less favorable latent statuses.
Poor physical health days (v036)	More poor physical health days were significantly associated with less favorable latent statuses.
Low [infant] birthweight (v037)	Higher rates of low infant birthweight were significantly associated with less favorable latent statuses.
Preventable hospital stays (v005)	Higher rates of preventable hospital stays were associated with less favorable latent statuses.
Life expectancy (v147)	Higher life expectancy was positively associated with being in a more favorable latent status.
Premature age-adjusted mortality (v127)	Higher premature age-adjusted mortality rates were associated with less favorable latent statuses.

Discussion

In the initial analysis, a cumulative logit model was selected to investigate the relationship between various predictors (community health effects) and the latent statuses of local health departments that were calculated through a latent transition analysis. The cumulative logit model is typically suitable for ordinal outcomes—*and potentially the most popular model for such needs* (*8.4 - The Proportional-Odds Cumulative Logit Model*, 2024)—as it assumes that the relationship between the predictors and the outcome is consistent across all thresholds of the ordinal variable. However, discovery that the test for the proportional odds assumption resulted in significant violation (Chi-Square = 851.8760, $p < 0.0001$) led to pursuit of alternative methods. The violation of the proportional odds assumption suggested that the relationship between the predictors and the latent status varies by category ('status'). This makes practical sense with respect to the prior findings of practical shortcomings with the six-status, two-time model (see Chapter 3). This inconsistency necessitated the use of an alternative model that does not rely on the proportional odds assumption.

To address the violation of the proportional odds assumption, a generalized logit model was employed (*The LOGISTIC Procedure: Iterative Algorithms for Model Fitting*, 2019). The generalized logit model relaxes the proportional odds assumption, allowing the relationship between predictors and the outcome to vary across different levels of the ordinal dependent variable. This flexibility makes it more suitable for these ordinal data, where the effects of predictors on latent statuses are not uniform. The generalized logit model revealed several significant predictors of latent statuses among LHDs. Particularly, the Type 3 Analysis of Effects revealed that several variables significantly influence the latent statuses of local health departments (e.g., poor physical health days with $p > .0001$ and Wald Chi-Square = 70.3210). These results suggest that the predictors may play important roles in determining the latent statuses of LHDs, while variation observed in outputs may underscore the complexity of factors impacting LHD configurations. The predictor effects may also highlight specific areas for policy intervention and resource allocation; an opportunity for future investigation.

However, despite the strengths of the generalized logit model, some predictors exhibited extreme odds ratio estimates and wide confidence intervals, suggesting potential issues with model specification or data scaling; it is likely that poor or fair health (v002) and low birthweight (v037) may be inappropriate for inclusion with this model. These findings highlight the need for careful interpretation and potential further investigation into data scaling or transformation to improve model stability.

Other studies have investigated other approaches toward empirically classifying and evaluating governmental health departments and their functions (Bekemeier et al., 2014). The present approach may be supportive of similar efforts to consider the 'design' of health departments—their structures, partnerships, and means of delivering services—as a factor in the success of local public health systems in effecting community health outcomes (Patorniti et al., 2017). Public health practitioners have also supported investigations into how public health systems may be designed or modified in order to improve the public's health. This includes measurement of impacts of different governance structures and partnerships that may serve to enhance efficiency or effectiveness of services (Center for Sharing Public Health Services, 2018). These changes to governance or service delivery paradigms can shift LHDs from one status to another and have the potential to "open the door" to new ways of services and resources sharing and appropriation (Bar-Yam, 2006; Hassmiller Lich et al., 2017; Madhavan et al., 2018).

Conclusions

Though the analysis initially aimed to use a cumulative logit model to explore the relationship between community health outcomes and the latent statuses of local health departments, the significant violation of the proportional odds assumption necessitated the adoption of a generalized logit model. The generalized logit model, which relaxes the proportional odds assumption, provided a more appropriate framework for our data. The findings from the generalized logit model identified several significant predictors of latent statuses, such that community health outcomes such as poor physical health days, preventable hospital stays, and life expectancy may possess some predictive power with respect to the configuration and functioning of LHDs. The study provides critical insights that can inform public health policy and strategic planning. Making changes to how local public health systems are designed, such as re-envisioning governance or pursuing partnerships, may improve life expectancy, reduce poor physical health days, and may address preventable hospital stays. Overall, this study contributes to a deeper understanding of the factors influencing the latent statuses of local health departments and provides a foundation for future research and policy development aimed at improving public health systems. The study also reveals some opportunities for further investigation and future research could explore alternative model specifications or analyses to enhance the robustness of the findings. By addressing the methodological challenges and leveraging the appropriate statistical models, researchers can gain more accurate and actionable insights into the complex dynamics of public health administration.

Chapter 5 – Conclusions

The studies included within this dissertation comprise a set of contributions to the fields of systems engineering and governmental public health and may serve to bridge and extend each sets of disciplines. Though the subject matter was rooted in governmental public health practice and concepts, the underlying theme prevails that considering governmental public health systems as being 'designed' or as being able to be abstracted are core to the purpose of systems engineering. It is my strong belief that every governmental public health system, headed by a governmental public health agency is perfectly designed to achieve the results that it receives. For many governmental public health systems, the present design statuses are woefully insufficient and rooted in paradigms that lead to inefficient, ineffective, and inequitable outcomes for communities.

The first essay was guided by the research question: *How may a systems approach toward design of governance structure and service delivery mechanisms of a public health system improve service delivery?* Through the investigation, I demonstrated the paucity of research and documentation for how governmental public health systems may be designed. While systems science methods are ubiquitous—perhaps only surpassed in ubiquity of how governmental public health systems may be classified—there appears to be minimal application to governmental public health systems. There are some pseudo-systems approaches in use by the public health field, including those championed by myself and others with the Center for Public Health Systems, but no prevailing systematic approach toward considering public health systems design. There are many opportunities to adopt systems engineering and related systems science techniques to support the abstraction, design, or analysis of governmental public health systems, perhaps starting with classification approaches.

The second essay was guided by the research question: *How can latent transition analysis be used to classify local health departments into distinct statuses based on governance, centrality, colocation, and integration, and what are the transition probabilities between these statuses over time?* Through the investigation, I utilized a novel approach toward classifying governmental public health systems, led by their local health departments (LHDs). The approach I employed leveraged latent transition analysis (LTA) as a means to classify LHDs according to variables from the National Association of County and City Health Officials' (NACCHO) National Profile of Local Health Departments (Profile) study. The LTA identified six distinct latent statuses for LHDs based on NACCHO variables by governance, centrality, colocation, and integration variables. The six-status, two-time model demonstrated the best statistical fit, with reasonable consistency observed across different seeds and parameters. Significant predictors of latent statuses included variables such as governance type, jurisdiction classification, and the presence of shared services. Findings indicate that there is an ability to classify and analyze public health systems according to underlying or latent classes or statuses.

The third essay was guided by the research question: *How do various community health outcomes influence the latent statuses of local health departments, as identified through latent transition analysis, and what are the significant predictors of these latent statuses through ordinal regression?* Through the investigation, I extended findings from the second and utilized the resultant typology in an effort to identify potential predictors of system structure and behavior. That study aimed to explore the relationship between community health outcomes and the latent statuses of LHDs by employing advanced LTA and ordinal regression models. The initial analysis using a cumulative logit model revealed a significant violation of the proportional odds assumption, necessitating the use of a generalized logit model to accurately capture the variability in the data. This shift in methodology allowed for a more nuanced understanding of the predictors influencing the latent statuses of LHDs. The generalized logit model, which relaxes the proportional odds assumption, provided a robust framework for analyzing the relationship between community health outcomes and latent statuses. The model identified several significant predictors, such as poor physical health days, preventable hospital stays, and life expectancy. Some predictors exhibited extreme odds ratio estimates and wide confidence intervals, suggesting potential issues with data scaling or model specification. The transition from a cumulative logit model to a generalized logit model underscores the importance of selecting appropriate methodologies to address specific data characteristics and assumptions. The study made clear that there are, indeed, ways to assess different configurations of governmental public health systems according to their outputs. This may then lead to informing how to approach designing (or redesigning) governmental public health systems in order to improve upon systems operations.

The findings from these studies provide valuable insights into the factors influencing the configuration and effectiveness of local health departments, guided by the different research questions and study aims. The significant predictors identified through the generalized logit model highlight critical areas for public health intervention and policy development. For instance, understanding the impact of governance structures and service delivery mechanisms on community health outcomes can inform strategic decisions to enhance the efficiency and effectiveness of public health systems. These studies further contribute to the fields of systems engineering and public health by demonstrating the utility of advanced statistical models, such as latent transition analysis and generalized logit models, in exploring complex relationships within public health data.

While these studies offer significant insights, several limitations warrant further investigation:

- It is likely that there are additional systems science and engineering approaches that may be applied to governmental public health that were not discovered during the systematic review. The governmental public health sector is not monolithic—knowledge from other sectors and disciplines can bring public health into the 21st century.
- The violation of the proportional odds assumption in the cumulative logit model highlights the need for careful assessment of model assumptions and potential alternative methodologies. This is a reminder not only that governmental public health systems may be complex, but there may also be substantial knowledge limitations that present barriers to systems analysis in public health.
- Extreme odds ratio estimates for some predictors suggest a need for further exploration of data scaling and transformation techniques to improve model stability with predictors. Further, data limitations identified through analytical processes highlights the importance of quality data collection by governmental public health agencies.
- Data quality issues and other data limitations were observed in the investigation which led to changes in variable selection, data years of study, etc. These findings may warrant additional investigation into the quality and appropriateness of generalizations with the NACCHO Profile or County Health Rankings & Roadmaps datasets. There may be future opportunities to improve response rates, completeness, consistency of responses, and other data quality elements.
- Future research should explore additional covariates and datasets to enhance the robustness and generalizability of the findings. There are numerous datasets and relevant

covariates for public health, ranging from core public health, healthcare, social services, government, and other sectors. Utilization of systems approaches such as systems dynamics or causal loop diagramming, complex adaptive systems techniques, and sociotechnical design are important opportunities.

In conclusion, I believe this study underscores the importance of understanding the structural and operational characteristics of local health departments and their impact on community health outcomes, with a lens of design and systems afforded through the systems engineering discipline. By leveraging advanced statistical models, researchers and policymakers can gain deeper insights into the complex dynamics of public health systems and develop more effective strategies for improving public health services. The findings provide a foundation for future research and policy development aimed at optimizing the design and functioning of public health systems to better serve communities. There are many opportunities at each of our fingertips and we should be inspired to collaborate together to seek them out.

Appendix A – Overview of Relevant Public Health Concepts

Public Health Governance

Public health governance is a critical determinant of how a public health system is designed to operate. For the purpose of this document, 'governance' is defined to be the process for both state and nonstate actors to interact, design and implement policies within a given set of formal and informal rules (World Bank, 2017). This governance takes place at every geopolitical level in the U.S. society, in sovereign tribal nations, in businesses and in collaborations between different institutions. Governance is a complex, multi-faceted concept that takes multiple forms and serves multiple functions. Arising from this complexity, public health systems have organized in a variety of ways across the nation. This complexity is understandable, given that the governmental public health system in the U.S. contains multiple federal agencies, state governments from fifty states (plus the District of Columbia), approximately 2,800 local governments, and 565 federally recognized tribal agencies (Hyde & Shortell, 2012). These variations are along dimensions of state-local control, openness to shared governance, explicit vs implicit authorities and other characteristics, as states have broad authority to design state and local governments as they wish. Sources of authority originate from the 10th Amendment to the U.S. Constitution (powers not delegated or prohibited are reserved to the states or people), police power of states, and delegation of authority from state to local government by constitution, statute, or home rule. Authority may be governing authority (policy-making and enforcement) or advisory in nature.

For the purposes of this document, governance is restricted to entities within the state public health system. Typically, the federal government's public health responsibilities lie within functions for research and the provision of assistance to lower government levels (Ogden, 2012).

State and local governments are generally responsible for program planning, implementation, and evaluation of service delivery at the state and local levels. Governance is a cross-cutting issue for all policy consideration and approaches to modernization work. The following subsections offer an overview of important governance concepts and structures before identifying potential issues for governance.

Overview of Governance Concepts

Governance Functions

A set of governance functions for public health governance have been identified in peer-reviewed research and supported by the National Association of Local Boards of Health (NALBOH) and the Centers for Disease Control and Prevention (CDC) (Carlson et al., 2015). The governance functions identified are the key domains of activity and accountability for governing bodies.[6] The taxonomy of the functions is as follows (Shah et al., 2017):

- **Policy Development**: lead and contribute to the development of public health policies to protect and improve the public's health while remaining consistent with governing authorities;
- **Resource Stewardship**: assure availability of adequate resources (legal, financial, human, technological and material) to deliver public health services;
- **Legal Authority**: exercise vested authorities to assure achievement of public health roles, responsibilities, obligations and functions;
- **Partner Engagement**: build and strengthen partnerships with all relevant stakeholders to support public health strategies and goals;

[6] Though the existing literature for public health governance often applies these governance functions to local boards of health, these functions may apply to any governing body.

- **Continuous Improvement**: decide upon accountability metrics (process and outcome) and routinely perform performance management for public health policies and activities; and
- **Oversight**: assume the ultimate responsibility for the performance of public health to achieve measurable outcomes.

These six functions are supplemented by additional characteristics and strengths, including governing body composition and member qualifications (where applicable), diversity of information sources used by governing bodies to seek community perspectives, meeting frequency and other governing body characteristics.

State Governing Bodies

Legislature

The state legislature is the ultimate authority for public health for a state, though it may also be said that the electorate vests this authority with their elected officials. Laws passed by a legislature may cover broad areas or specific situations and written statutes typically either a) direct a certain activity, b) prohibit a certain activity, or c) declare policy. State legislatures approve state public health agency budgets, pass public health laws and regulations, and set fees and tax levies to pay for public health services (Public Health Law Center, 2015). Importantly, legislatures may pass "enabling statutes" grant authority to both public and private entities and establish the legal foundation for financing, organizing and delivering public health services (Hoss et al., 2016). These enabling statutes delegate power to entities so they may address more broad public health laws. As mentioned previously, states have broad authority to design state and local governments as they wish, allowing for differing strengths of "home rule"[7], which is

[7] When an authority has not been explicitly granted to a local government, most states follow "Dillon's Rule" as a means to determine whether power is granted to local governments. Dillon's Rule is a narrow interpretation of

the limited autonomy or self-government granted to local governments outside of explicit authorities from legislatures (Fisher & Shelley, 2018). For the purposes of this document, local governments are the dependent political units within the state and include counties, cities, and any other municipalities which represent a political or taxing subdivision of the state as well as commissions, authorities, or quasi-municipal corporations created by state law; most local public health departments and local public health activities occur at the county level.

State Board of Health

A state health council or board of health (SBoH) is a body created by the state legislature to lead, guide and oversee delivery of public health services for the protection and promotion of health in the state. This board advises and oversees the state health agency or department and may provide advising to other state government for health-related topics. Members of SBoHs are often gubernatorial appointees and may represent multiple disciplines or stakeholder groups, often from health care, business, education, or as citizens or consumers (Public Health Law Center, 2015). Primary activities of these boards are to promulgate rules; advise elected officials on public health policies and concerns; develop state public health policies; and develop legislative public health agendas (Hyde & Shortell, 2012). Though sometimes referred to synonymously, a state health council is not the same as a state board of health and does not possess the same governing authority.

Approximately sixty percent of all state public health departments are governed by a state board or council of health (Public Health Law Center, 2015). Following an apparent budget crisis involving multiple Oklahoma State Department of Health officials, the state Board of Health,

local authority which may limit local government authority to act outside of explicitly granted powers. Home rule, whether constitutional or statutory, offers local governments more flexibility than Dillon's Rule to operate.

and other actors, the state legislature commissioned an audit which highlights, in part, considerations for a state board of health (Sixteenth Multi-County Grand Jury of Oklahoma, 2018, p. 30):

"The Board of Health had a duty to act not just as advisors or advocates for public health, but to fulfill its fiduciary duty as required by statute and ensure that public health is managed in a fiscally appropriate and sound manner… Unpaid volunteers with no knowledge or experience in state government cannot be expected to exercise such a duty... The Multi-County Grand Jury notes and commends the change in structure of the Board of Health resulting in it serving only in an advisory capacity."

State Health Department

State health agencies or departments (SHDs) are generally the primary public health authority within a state and may be structured as an independent or free-standing agency within state government or may be located within an "umbrella agency" or "super agency", such as within a department of health and human services (*similar to how the CDC is located within DHHS*) (Hyde & Shortell, 2012). The governor in most states appoints the SHD director or secretary of health in addition to appointing a medical director or advisor to the SHD. Some ancillary public health functions are shared by "sister agencies" within state government, such as the licensure of health care professionals or inspection of health care facilities by other state boards or departments (Public Health Law Center, 2015). SHDs, and other sister agencies with regulatory authority, have the power to adopt rules and regulations, as authorized by the legislature. Duties of a state health department often include (Office for State, 2013):

- disease surveillance, epidemiology, and data collection;
- state laboratory services;
- preparedness and response to public health emergencies;

- population-based primary prevention;
- health care services;
- regulation of health care providers and other licensed professions;
- environmental health; and
- technical assistance and training.

While some independent health departments often focus exclusively on traditional public health authorities, others provide additional services such as administration of Medicaid. Umbrella agencies are often responsible for a multitude services related to public health, health care, and other human services. SHDs are independent in fifty-five percent of states, while the remaining SHDs are incorporated into a larger umbrella agency (Hyde & Shortell, 2012). Trends seen in surveys over time may indicate a shift toward further integration of SHDs into umbrella agencies across the U.S., largely due to fiscal pressures in the state government. There may be the potential for integration to hinder overall public health performance following decreased focus and independence, though no research has been identified to confirm or dispute concerns.

All fifty states have a form of state public health agency and have reported maintaining a sum total of 312 regional or district offices of the state across the nation (as few as zero but as many as sixty-eight in a state with a mean of six) (Association of State and Territorial Health Officials, 2017).

Local Governing Bodies

Local Board of Health

A local board of health (LBoH) is a legally designated body whose members are appointed or elected to lead, guide and oversee delivery of public health services for the protection and promotion of health in its community (Jones & Fenton, 2012). Boards are generally the same governing body as the local government, such as a board of county commissioners. Some states enable boards to have local government representation with the addition of other persons who are appointed or elected. Similar to SBoHs, other members may represent multiple disciplines or stakeholder group, often from health care, business, education, or as citizens or consumers. The role, legal authority and regulatory power of LBoHs vary by enabling authorities and by jurisdiction, though all are obligated to enact policies to improve the health of their jurisdiction. In contrast to SBoHs, LBoHs are responsible for policy making, priority setting, data collection and analysis, financing, and oversight of local public health activities (Hyde & Shortell, 2012). The LBoH has the sole authority over local public agencies or departments in their jurisdiction, with exception of the special cases, below. Currently, local boards of health govern approximately seventy-six percent of local health departments in the United States (National Association of County and City Health Officials, 2017; Shah et al., 2017).

Local Health Department

Local health agencies or departments (LHDs) are organized similar to SHDs and may be an independent agency or located within an umbrella agency in local government. LHDs are often located at the county level but may also exist within or in partnership with other local government. These authorities may span within a single geopolitical jurisdiction or across multiple jurisdictions. The LBoH (or joint board) is tasked with appointing a LHD director or administrator in addition to a local medical director or advisor, as defined by statute. Enabling statutes for each state outline roles and regulatory authorities for LHDs, often separate from roles and authorities for SHDs. Duties for LHDs typically aim to support the 10 EPHS. Depending upon jurisdiction size and resources, health departments may provide a broad range of functions (e.g., urban LHDs) or a narrow set of services (e.g., frontier LHDs).

In 2016, all fifty state public health agencies reported to the Association of State and Territorial Health Officials (ASTHO) having a total of 2,795 local health departments which is consistent with the National Association of County and City Health Officials (NACCHO) estimation that there are approximately 2,800 agencies or units that meet the NACCHO definition of a LHD (Association of State and Territorial Health Officials, 2017; National Association of County and City Health Officials, 2017). This encompasses a variety of local, county, city, district, and regional public health departments with variations by state (as few as zero to a maximum of 351 with a mean of 42 LHDs and a median of fourteen LHDs)[8].

Special Case – Integration with State Government

In some cases, LHDs are extensions of the SHD as a part of a centralized authority; this is described below in *State-Local Governance Classification*.

Special Case – Integration with Other Local Government

In other cases, local governments may combine entirely (as in a unified city-county government) or may decide to consolidate or merge public health authorities across geopolitical jurisdictions with joint authority offered by each partner government. In some instances, the state may create a special district for regionalized services. These are examples of a highly integrated form of "cross-jurisdictional sharing" (CJS) is described below in *Public Health Service Delivery*.

Tribal Governing Bodies

The American Indian and Alaska Native tribes ("Tribe") are each their own sovereign nations with inherent authority to protect and promote the health and welfare of their citizens

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[8] Massachusetts has the most number of local health jurisdictions of any state with 351 local health jurisdictions. Massachusetts has no county government and each municipality (city, town, township) retains authority over their own jurisdiction.

(Hoss et al., 2016). This inherent authority allows exclusive power over tribal members, limited only by federal law, and allows tribes to determine their form of government which includes the powers of legislation, enforcement, taxation and other governing powers. There are 573 federally recognized tribal authorities across the nation according to the Bureau of Indian Affairs (Bureau of Indian Affairs, 2018).

Indian Health Service

The national Indian Health Service (IHS), incorporated within DHHS is the lead federal agency representing the health needs of Tribal citizens. IHS, as well as local and state health departments, often deliver services directly or in partnership with the Tribes through self-determination contracts (Title I) and self-governance compacts (Title V) authorized within the Indian Self-Determination and Education Assistance Act (ISDEAA) (Congressional Research Service, 2018; Knudson et al., 2012). Tribes may access IHS through one of the twelve Area Offices. Some Tribes are a part of a program granting more autonomy in self-determination, the Tribal Self-Governance Program (TGSP), which includes ten of the IHS Areas.

National Indian Health Board

The National Indian Health Board (NIHB) is a 501(c)3 not-for-profit charitable organization serving all federally recognized Tribal governments as a means to ensure federal accountability to provide health care to Tribes. NIHB advocates on behalf of member Tribes and aims to provide the public a better understanding of health matters affecting Tribal citizens through research, education, and promotion of healthy activities. NIHB operates similar to a state health advisory council with respect to all member Tribes.

Tribal Health Departments

Tribal health departments (THDs), as defined in the ISDEAA, may be an entity arising from a federally recognized Tribal government, a Tribal organization, or an entity arising from an inter-Tribal consortium. Each entity is granted jurisdictional authority to provide public health services from their Tribal governance and may carry out public health functions cooperatively by agreement or other arrangement. Not all Tribes or states have THDs due to population or resource restrictions of Tribes. Services provided by THDs are similar to those provided by LHDs and are influenced by the size of population served and geographic location (Knudson et al., 2012). THDs may be more integrated with the health care system than LHDs.

Health Officers

Separate from the authority of governing bodies, authority may be granted to elected or appointed health officers. Enabling authorities exist to grant broad responsibility and authority to state health officers (SHOs) who are directed to ensure the health of the public. Enabling authorities also exist to grant responsibility and authority to local health officers (LHOs) within their local governing jurisdiction. Health officers may or may not be the top executive of their jurisdictional health department (i.e., secretary of health or health department director). The function of government officials in any area is dependent upon the definition of the official's functions under relevant state law. State laws may give both LHOs and SHOs complete authority to enforce state public health laws in their covered jurisdictions.

State-Local Governance Classification

In 2011, the Association of State and Territorial Health Officials (ASTHO) and the National Association of County and City Health Officials (NACCHO) were funded by the Centers for Disease Control and Prevention (CDC) to develop a consistent classification scheme for state and local governance (ASTHO & NORC at the University of Chicago, 2012). The report, supported by research from NORC at the University of Chicago, outlined an algorithm using criteria related to 1) leadership of local health units and 2) governmental public health authority to classify state governance. There may be a number of tradeoffs depending upon which scheme may be in place within a state, as exampled within **Figure 3**, below.

The following four categories are incorporated into the classification scheme (updated in the 2016 ASTHO Profile) (Association of State and Territorial Health Officials, 2017):

Centralized and Largely Centralized Governance

Centralized Governance occurs in those states in which there are no local health units or when the entire state population is served by local health units that are extensions of the state (led by state employees) and the state retains authority over many decisions relating to the budget, public health orders, and the selection of local health officials. Largely Centralized Governance occurs when the majority (seventy-five percent or greater) but not all of the state population is served by the state government.

- **Centralized Governance**[9]: AR, DC, DE, HI*, MS, NM, RI*, SC, VT
- **Largely Centralized Governance**: AL, LA, NH, SD, VA

Decentralized and Largely Decentralized Governance

Decentralized Governance occurs in those states in which the entire state population is served by local health units from local governments (led by local employees) and the local governments retain authority over many decisions relating to the budget, public health orders, and the selection of local health officials. Largely Decentralized Governance occurs when the majority (seventy-five percent or greater) but not all of the state population is served by local governments.

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[9] Hawaii and Rhode Island state health departments operate on behalf of local public health and have no sub-state units.

- **Decentralized Governance**: AZ, CA, CO, CT, IA, ID, IL, IN, KS, MA, MI, MN, MO, MT, NC, ND, NE, NJ, NY, OH, OR, UT, WA, WI, WV
- **Largely Decentralized Governance**: NV, TX

Shared and Largely Shared Governance

Shared Governance occurs when the entire population is served by a scheme in which either 1) state government-led local health units (centralized) allow for limited local autonomy and authority or 2) local government-led local health units (decentralized) allow for limited state autonomy and authority. In these instances, a primary governance may retain enabling authorities such as the ability to issue public health orders or appoint and approve local health officials while the secondary governance may retain authority over budgetary or taxation authorities. Largely Shared Governance occurs when the majority (seventy-five percent or greater) but not all of the state population is served by this shared scheme.

- **Shared Governance**: FL, GA, KY
- **Largely Shared Governance**: MD

Mixed Governance

Mixed Governance occurs when there is a combination of centralized, shared, and/or decentralized arrangements across the state but no one scheme predominates in the majority of the state.

- **Mixed Governance**: AK, ME, OK, PA, TN, WY

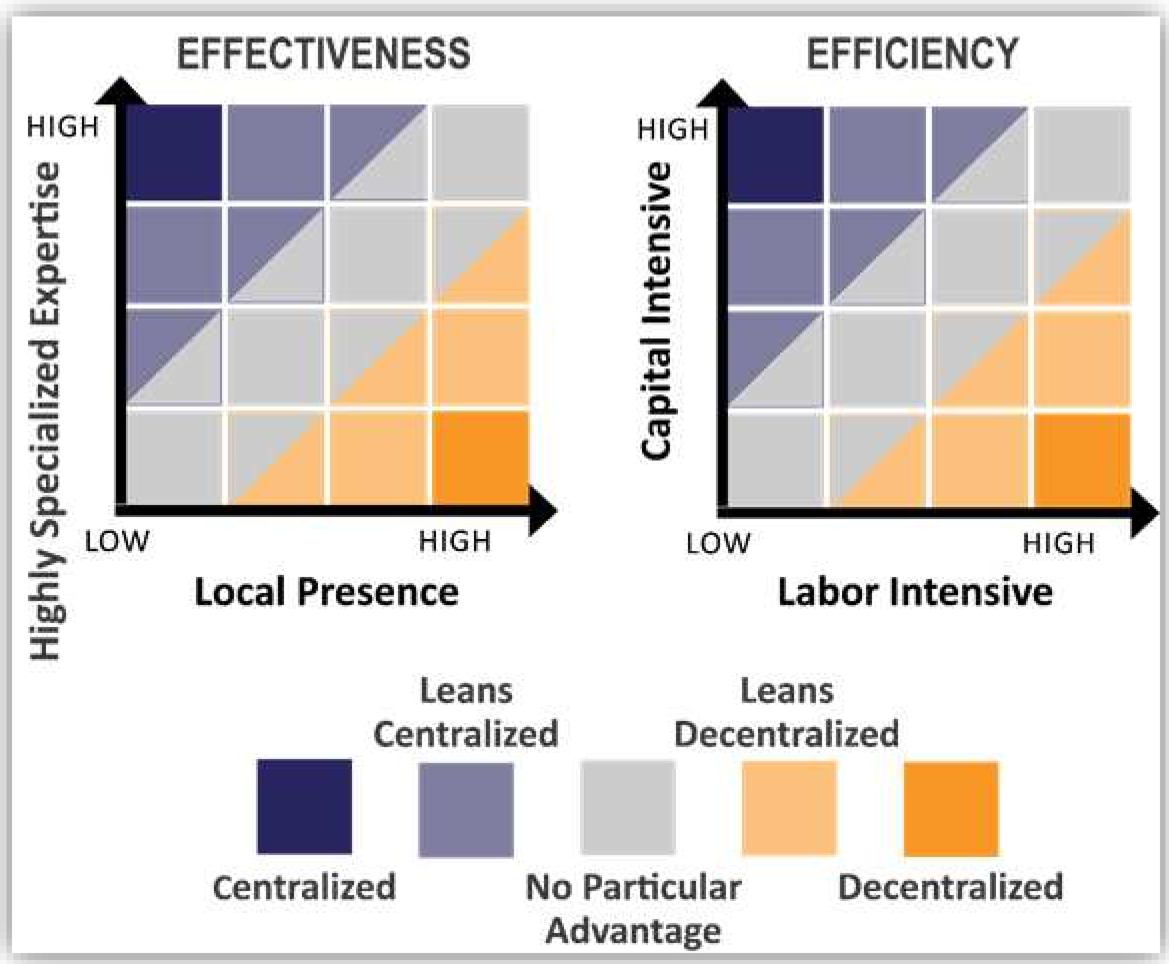

Figure 3. Advantages and Disadvantages of State-Local Governance Classifications

Source: BERK Consulting, 2017.

Public Health Service Delivery

For the purpose of this document, 'public health services' are defined to be public health capabilities or programmatic areas that reflect criteria for the Foundational Public Health Services (FPHS):

- Population-based preventive health services that target specific communities defined by geography, race, ethnicity, gender, illness, or other health conditions (e.g., water fluoridation, creation of walkable communities);

- Governmental public health is the only or best potential provider of service (e.g., disease surveillance and epidemiology); or
- Mandated service provided by the public health authority (e.g., communicating reportable disease cases to the state health department).

These services align with the public health models discussed above and extend to those services likely to governed within a jurisdiction.

For the purpose of this document, 'service delivery' is defined to be the means in which services are delivered or made available within a jurisdiction. As described above, services may include transactional activities, such as responding to requests for assistance, but may also include policymaking and health promotion campaigns. Services may also be internal capabilities and processes that cross-cut programmatic activities. Services are provided by "delivery agents" which may be thought of as either individual staff or a public or private agency as a whole; these agents are the actors within the system. As described in the following subsections, services may be delivered 1) by both public and private agencies, and 2) via any single agency or combination or configuration of multiple entities.

Governance and Service Delivery

The prior section focused on the governance of public health services. Governance and service delivery are two sides of the same coin, so to speak. The governance of a state, region, or locality affects many aspects of service delivery. As described within the **State-Local Governance Classification** subsection, above, the level of decentralization within a state has a strong role in determining jurisdiction throughout a state and, similarly, who the primary delivery agents may be; the governance classification identifies the basic governance paradigm. Jurisdictions may decide to collaborate along continuums of inter-agency integration or interdependence. In each case, the governing body(ies) maintain decision-making authority for how services are to be delivered. Each of the special cases listed above illustrate both a change in governance and in mechanism of service delivery as the responsibility for a jurisdiction's public health is consolidated, merged, or regionalized across multiple jurisdictions.

Service Delivery Paradigms

Many different paradigms exist for the delivery of public health services and can be applied to individual services or functions, such as financial management or a public health preparedness program, or to the entire health department. Paradigms may fall under three different categories for a given service or sets of services: *no service(s) provided* (no delivery agents), *independent service delivery* (single entity governs and delivers services), or *collaborative service delivery* (multiple entities work together to deliver services).

The predominant paradigm for most public health is for the local government (decentralized), state government (centralized), or Tribal government (centralized) to be the sole entity that independently delivers services. In some cases, however, there may be services that are commonly provided by governments in a state but not exclusively provided by governments. An example of this instance is when a county's community health assessment and improvement planning process is not overseen by the local government but by a coalition or private entity; in this instance the service is not 'governed' by the local government but by the private sector. Entities that typically retain independent governance and service delivery are as follows:

- **State Government (centralized):** SHD or other state government department is agent of delivery in local jurisdictions;
- **Tribal Government (centralized):** THD or other Tribal department is agent of delivery in Tribal jurisdictions;

- **Local Government (decentralized):** LHDs or other local government departments are agents of delivery in local jurisdictions; and
- **Private Organization (privatization or private commercial enterprise[10]):** private organizations (non-profit or for-profit) are agents of delivery in local jurisdictions.

Each of the governments listed are public entities; a public body may be a board, department, or other similar authority. The following subsections detail mechanisms of collaborative service delivery.

Collaborative Service Delivery

Collaborative service delivery is a tantalizing alternative for a jurisdiction that may not have sufficient resources to efficiently or effectively deliver a service on their own. Arrangements ranging from informal handshake agreements to contracts to joint oversight or consolidation may lead to improved efficiency and effectiveness in delivery to the public. There are various drivers toward collaborative service delivery and the major drivers may be summarized, as follows (Kaiser, 2011):

- A constant evolution of policy that leads to numerous and complex programs;
- Pressures to reduce the size and scope of government and to cut expenditures;
- Pressures to increase and improve partnerships with other agencies and jurisdictions; and
- Emergent crises that create urgency in restructuring governmental interventions.

The decision to pursue collaboration should arise from a desire to enhance quality of existing services or to maintain or expand services in light of budget limitations. Overall, collaborations serve to advance priorities for resource-restricted communities and provide greater

[10] Privatization is distinguished from a private commercial enterprise in that the former is a public service divested to a private entity with limited control retained by governmental entity while the latter is completely non-governmental.

access to professional expertise. Economy of scale is an important factor in the decision as there may be improvements to efficiency or effectiveness of service delivery above a certain threshold of resources. There are several factors to consider in the decision to collaborate and selection of a service delivery paradigm: *partner schemes*, *governance of arrangement*, and *type of arrangement*. Each of these are described below.

Partner Schemes

The selection of partners is an important consideration for any partnership as there are benefits and challenges associated with the partners included in any arrangement. One consideration for partner selection is "asset specificity", or the degree of need for infrastructure or technical expertise, as it may be a strong determinant for partners to be selected (Hilvert & Swindell, 2013). There may be few partners within the market that have needed skills or infrastructure. Significant legal considerations are also present, depending upon partners in the arrangement, and the difficulty in managing a contract should be weighed. Partners may be public authorities (boards, officials, etc.), private entities, and may even be two departments of the same government. These partner schemes may fall under four categories:

- **Intra-Governmental (or "inter-departmental"):** collaboration between two or more agencies or departments of the same government;
- **Public-Public ("cross-jurisdictional sharing"):** collaboration between two or more governments
- **Public-Private ("public-private partnership"):** collaboration between at least one governmental agency and at least one private agency; or
- **Private-Private:** collaboration between two or more private agencies.

There may also be "nesting" of arrangements in which more than one schemes are in place (e.g., a public-private partnership between a quasi-governmental entity and a local government). Two schemes are of note:

Public-public sharing, or "cross-jurisdictional sharing" (CJS), is defined as "*the deliberate exercise of public authority to enable collaboration across jurisdictional boundaries to deliver public health services and solve problems that cannot be easily solved by single organizations or jurisdictions*" (Center for Sharing Public Health Services, 2013). The Center for Sharing Public Health Services has served as a national resource on CJS since 2012, amassing evidence on the tool and disseminating methods and models to assist in the use of CJS in improving efficiency and effectiveness of service delivery. These arrangements may be between multiple levels of government, sometimes considered "vertical" (i.e., a state-county arrangement), or between units of government at the same level, sometimes considered "horizontal" (i.e., a county-county arrangement) (Hilvert & Swindell, 2013).

Public-private sharing, or public-private partnerships (PPPs) are long-term contracts between a private party and government entity for providing a public asset or service in which the private party bears significant risk and management responsibility (International Bank for Reconstruction and Development, 2017). PPPs are described in terms of three parameters: *type of asset involved, functional responsibilities of private party,* and *how private party is paid*. The PPP Knowledge Lab of The World Bank Group, in collaboration with other international partners provides multiple tools to help decision-makers and practitioners to disseminate good practices on infrastructure and implementation of PPPs.

Governance of Arrangement

The governance of a service, program, or department is another important consideration and is a primary determinant for the service delivery paradigm. An entity with authority or control over services may decide to collaborate with a public body or private organization but retain responsibility and control over services. In other instances, that entity may want to retain responsibility but share control of delivery of services. Finally, there may be instances in which the entity pursues an arrangement in which their governance is combined with a public body or private organization. This range of options also falls along a spectrum of integration or interdependence, as described below. Governance arrangements are discussed in detail within the previous section.

Types of Arrangements

The type of arrangement is a third critical factor in leading to the collaborative service delivery paradigm. Alongside the partners within the arrangement and the determination of governance for a jurisdiction, the depth of partnership is an important determinant. Arrangements along any partner scheme may be viewed to fit along a continuum or spectrum of formality or integration.

Spectrum of Public-Public Arrangements

For public-public sharing, the Center for Sharing Public Health Services describes the types of CJS arrangements fitting into the following categories along a spectrum of increasing inter-agency integration (see **Figure 4**) (Center for Sharing Public Health Services, 2017):

- **As-Needed Assistance**: informal or customary arrangements that are episodic in nature;
- **Service-Related Arrangements**: regular and predictable sharing arrangements formalized by contracts;

- **Shared Programs or Functions**: arrangements in which all entities contribute resources and have a formal role in decision-making for the delivery of services;
- **Regionalization/Consolidation**: arrangements in which a single governmental entity delivers all services within a multi-jurisdictional service area and assumes all risks, costs, and decision-making for the jurisdictions.
    - ***Consolidation***: *a governmental entity acquires one or more agencies into itself but retains same identity;*
    - ***Merger***: *a governmental entity acquires one or more agencies into itself to create a new entity; and*
    - ***Regionalization:*** *creation of a special district or a new entity to service a geographic area.*

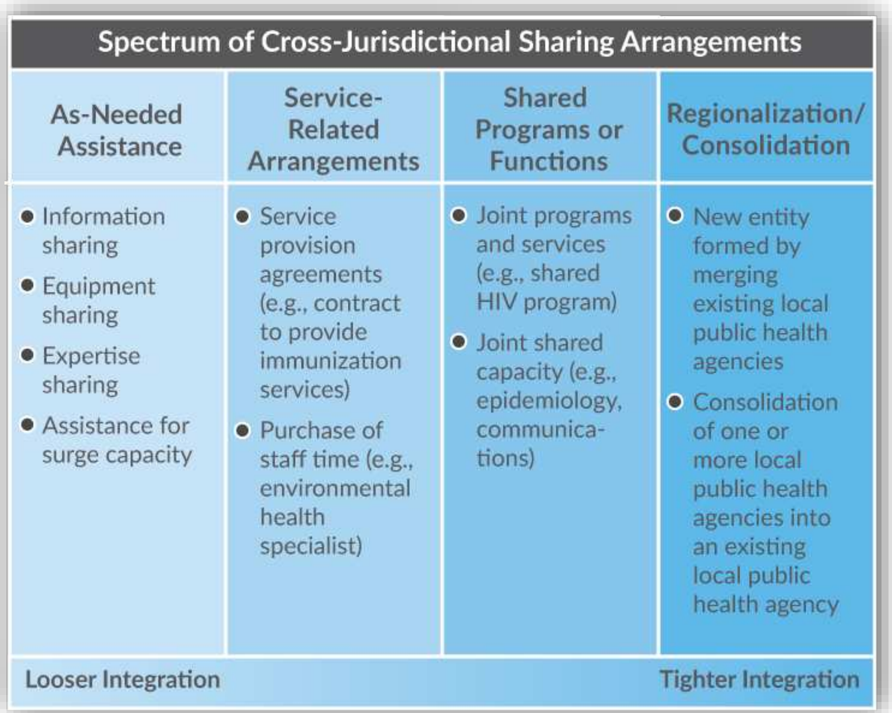

Figure 4. Spectrum of Cross-Jurisdictional Sharing Arrangements

Source: Center for Sharing Public Health Services. (2017).

Spectrum of Public-Private Arrangements

For private-private sharing, the World Bank Group's Public-Private-Partnership Legal Resource Center (PPPLRC) describes the types of PPP arrangements along a spectrum of increasing private sector participation (see **Figure 5**) (International Bank for Reconstruction and Development, 2017; Public-Private-Partnership Legal Resource Center, 2016):

- **Public Owns and Operates Assets**: governmental entity retains authority, control, risk, and assets of service delivery and receives limited assistance from private entity (*often one-sided or transactional*);
    - ***Reform/Restructuring**: governmental entity receives assistance from private entity in a reform or restructuring process to consolidate operations and improve accountability to stakeholders; and*

- ***Civil Works and Service Contracts**: governmental entity contracting with private entity for goods or services as-needed.*

- **Public-Private Partnership**: governmental entity and private entity share authority, control, risk, and existing assets of service delivery with private entity delivering services (*often mutually beneficial*); and
    - ***Management and Operating Contracts**: governmental entity contracting out services for existing infrastructure to private entity for operations and maintenance in a fixed price or performance-based arrangement (short term, 2 – 5 yrs.);*
    - ***Leases and Affermage Contracts**: governmental entity remains responsible for financing and managing existing assets but private entity maintains and operates services, takes on risk, and charges fees to consumers;*
    - ***Concessions/Build-Operate Arrangements**: output-focused arrangements in which new initiatives or expansion of services is desired with governmental entity temporarily transferring existing assets to private entity which delivers services in exchange for revenues from the consumer; and*
    - ***Joint Venture and Partial Divesture**[11]: governmental entity and private entity each have an equity stake ("shares") and joint ownership in project while asset ownership and management may be public or private and service delivery is delegated to private entity.*

- **Private Sector Owns and Operates Assets**: governmental transfers significant authority, control, risk, and existing assets to private entity[12].

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11 Public entities may be restricted by law from entering into a joint venture.

12 Distinguished from a private commercial enterprise (non-governmental activities) in that the governmental entity retains some indirect form of control or mechanism for regulation via license or other means.

- *Full Divesture ("privatization"): governmental entity divests of assets by sale or transfers them to a special purpose company created by the government as a means for the private entity to take over all aspects of service delivery.*

Figure 5. Spectrum of Public-Private Partnership Agreements

Source: Public-Private-Partnership Legal Resource Center (2016).

Comparing the two spectra shown above, it may be understood that both public-public and public-private arrangements fall along similar continua of integration and inter-dependence. Though, it is important to note that on the extreme right ends of each spectrum the partnerships are no longer a balanced share of activities. For highly integrated public-public arrangements, the arrangement operates as an independent delivery of services with a different entity overseeing an expanded service area. For a public-private divesture, the arrangement similarly operates as an independent delivery of services but with a different entity overseeing the service area.

National Context for Collaborative Service Delivery

Resource sharing is a common activity within public health. A 2012 analysis of NACCHO's 2010 Profile Survey showed approximately half of local health departments have reported resource sharing activities (Vest & Shah, 2012). This was also found in the NACCHO

2016 National Profile of Local Health Departments (National Association of County and City Health Officials, 2017). It is very common for public health services (and other public services) to be delivered collaboratively on an as-needed basis with agreements such as with memorandums of understanding (MOUs) or formal service contracts (e.g., nurse sharing agreements). The 2016 NACCHO Profile indicated that the most common arrangements are providing and/or receiving functions or services (thirty-five percent of LHDs responding), followed by staff sharing (thirty-one percent of LHDs responding), then followed by equipment sharing (twenty-five percent of LHDs responding). Regular or sporadic partnerships and collaborations occur across sectors, including with health care partners, community-based partners, and other government sectors. However, all types of formal LHD partnerships and collaborations included within NACCHO surveys decreased from 2008 to 2016 by an average of twelve percent. The sharpest decreases were seen between LHDs and emergency responders, hospitals, and K-12 schools (approximately twenty-two percent less formal agreements).

Shared or joint oversight of sharing arrangements are a bit less common, likely due to the complexity of arrangement and influence of governing responsibility or authority. States like Colorado and Kansas have arrangements in place for regional coordination of programs by third-party public health partnerships or regional interlocal agreements, respectively. Many states also provide a unique mechanism of joint oversight via "councils of government" (CoGs) or regional planning commissions with prominent public health examples in Ohio and Massachusetts, respectively.

There is a trend of governmental activity toward developing hybrid public-private entities called *quasi-governmental entities* ("quagos") and *quasi-non-governmental entities* ("quangos") (Mead & Warren, 2016). Quagos are government-created, independent entities with oversight by publicly appointed persons, such as the national Legal Services Corporation, turnpike authorities, and government-created health non-profit health agencies (Howard, 2017; Kosar, 2011). These organizations are not purely public nor are they purely private. Quangos are private, independent entities that receive delegated authority from the government to deliver services, such as the American Red Cross and some hospital-run health departments. Most private entities who are delegated authority to deliver services on behalf of a government are quangos.

Health Department Internal Organizational Structure

While unlikely to be incorporated into law or regulation, the internal organizational structure of the delivery agent impacts the delivery of services and is an issue of the entity's policy. The organizational structure in place may influence the efficiency and effectiveness of service delivery. Organizational structure may be influenced by the level of differentiation, or breadth, of programs or services provided and may also be affected by a collaborative service delivery arrangement in place in which external staff, whether from another governmental department or separate entity, interact or co-locate with department staff. It may even affect the billing and reimbursement paradigms in place within the entity.

Internal organizational structure defines the formal reporting relationships (hierarchy) and span of control of managers and supervisors (Pinto, 2015). This the structure may outline communication, coordination, and integration of effort within and across departments and agencies. Personnel may be grouped by activity or function, product or project, or by geographic location.

Three overarching forms of internal organizational structure exist:

- **Functional Structure (*contemporary LHDs*)**: internal structure in which personnel are grouped by the types of activities or services they provide (e.g., LHD staff organized underneath programs);
- **Project Structure (*nimble private organizations*)**: internal structure in which personnel are grouped by project team in temporary assignments (e.g., LHD staff shifted across department as needed for services); and
- **Matrix Structure (*dual hierarchy*)**: internal structure in which both functions and projects have equal prominence with supervision hierarchy underneath either functional departments or project managers.
    - ***Weak Matrix (functional):*** *functional managers control resources and manage own staff involved in project work coordinated by project managers;*
    - ***Strong Matrix (project):*** *project managers control resources and manage staff assignments with limited supervision by functional managers; and*
    - ***Balanced Matrix (equal):*** *equal distribution of authority and resource assignments with shared responsibility by functional and project managers.*

Functional structure is suited for environments with relatively low levels of external uncertainty with work falling under categorical functions (Pinto, 2015). These structures are efficient with consolidated expertise within departments or programs. Functional siloing and poor responsiveness to external opportunities or threats as well as a lack of central project management leads to poor performance. This structure is typical for most categorically funded LHDs and other entities with compact departments across the nation.

Project structure is best suited for organizations in which activities occur via short- or long-term projects. These structures centralize authority which allows for faster decision-making and communication and facilitates rapid response to external opportunities or threats. The structure, however, creates stresses for project staff at the start and conclusion of projects, and are typically more expensive. This structure is typical for private organizations and quasi-non-governmental organizations providing services by contract.

Matrix structures are needed for complex but dynamic organizations and are beneficial when there are pressures to share scarce resources or there is an emphasis on multiple types of output, such as a strong functional expertise paired with a need to develop a series of new products. A strong, weak, or balanced form depends upon the needs of the organization. These structures encourage close coordination and maximize use of resources. The structure may require significant time spent negotiation resources between managers and may frustrate project staff with multiple authority points. This structure is typical for diverse private or quasi-nongovernmental organizations that maintain dedicated services while remaining responsive to external needs.

Public Health Services Models

The defining feature of any public health system is the model from which a system's definition of "public health" is derived. This model is developed following an articulation of vision and purpose for public health to establish the 'why' for delivering public health services. Models for public health services are frameworks that describe the priorities for public health activities in support of the public's health. These models take on many forms and often include a scope of specific functions or capabilities to be carried out by agents of service delivery (typically governmental public health) and may also include programmatic areas or domains of this work. Some models go as far as specifying standards for levels of service or identifying competencies and skills to be held by delivery agents. Ultimately, these models outline a framework to be used for planning, priority-setting, and in ensuring accountability (Institute of Medicine, 2012).

Over the years, most public health services models have been discrete sets of services that governances labeled as ‘essential’, ‘core’, ‘basic’, ‘foundational’ and other similar terms. Each of these models defines services that should be available to all citizens, often delivered by governmental public health. Services included within these models may be most appropriate[13] when meeting the following decision characteristics:

1. services that are mandated by federal or state laws;
2. services for which the governmental public health system is the only or primary provider of the service, statewide; and
3. population-based services (versus individual services) that are focused on disease prevention, protection, and health promotion.

These models have been authorized in different ways by governing bodies. While the Centers for Disease Control and Prevention (CDC) underneath the U.S. Department of Health and Human Services (DHHS) are unable to do more than promote models (such as the 10 Essential Public Health Services), states have taken different steps to authorize their models such as adding the models to public health statutes, promulgating models into administrative rules or including them within administrative references (Orr, 2017).

Other models have arisen, such as the Public Health Accreditation Board’s (PHAB) *Standards and Measures* which defines services with domains of accountability metrics.

[13] The circular logic may be noted here for the ‘governmental public health’ and ‘mandated’ decision characteristics as the services selected for the model may or may not be currently carried out by governmental public health or mandated. From the list of possible services and components available in other states and jurisdictions to include in the model, those mandated or carried out by other governances may be stronger candidates to select.

Recently, following guidance by the IOM, the concept of a 'minimum package of public health services' has taken hold, with many governances adapting an articulated 'Foundational Public Health Services' model.

The definition of a model is the most critical step of the modernization process and is performed before all other steps. It is important to include within this document a clear understanding of the infrastructure provided by a public health model, as the central feature of the modernization work. Common models for public health services as well as an overview of certain state models are discussed in the subsections, below.

Common Models for Public Health Services

A brief review of the most common national models for the delivery of public health services is discussed below with significant advantages and disadvantages highlighted.

The 10 Essential Public Health Services

In the 1980s, the IOM membership came to the decision that the nation had lost sight of public health goals and that the national public health system had fallen into disarray. To address this, a study on public health was undertaken, the first of many over the years, to better identify this issue. The IOM tasked the *Committee for the Study of the Future of Public Health* to bring difficulties of public health to light to serve as a mechanism for change (Institute of Medicine, 1988). The committee asserted in their 1988 report, *The Future of Public Health*, that "the core functions of public health agencies at all levels of government are *assessment*, *policy development*, and *assurance*." Though concise, these **Three Core Public Health Functions** were found to be too broad to be their own model. The IOM then tasked another body, the *Core Public Health Functions Steering Committee*, to develop the framework for the **10 Essential Public Health Services** ("10 EPHS") in 1994 (Public Health Functions Steering Committee, 1994). The 10 EPHS improved upon the Three Core Public Health Functions by defining distinct services within each of the functions:

Assessment

1. Monitor health status to identify and solve community health problems;
2. Diagnose and investigate health problems and health hazards in the community;

Policy Development

3. Inform, educate and empower people about health issues;
4. Mobilize community partnerships and action to identify and solve health problems;
5. Develop policies and plans that support individual and community health efforts;

Assurance

6. Enforce laws and regulations that protect health and ensure safety;
7. Link people to needed personal health services and assure the provision of health care when otherwise unavailable;
8. Assure competent public and personal health care workforce;
9. Evaluate effectiveness, accessibility and quality of personal and population-based health services; and

Cross-cutting through all three functions

10. Research for new insights and innovative solutions to health problems.

Together, the Three Core Public Health Functions and the 10 EPHS created a framework to categorize all governmental public health services for community and population health, but this proved to have limited applicability for planning and setting priorities in the face of limited funding (Institute of Medicine, 2012). This provides an added difficulty in incorporating the 10

EPHS, solely, into public health policy. This model is currently promoted by the DHHS and CDC, though both are supportive of contemporary state-specific models.

For more information, please view *The Public Health System & the 10 Essential Public Health Services* on the CDC website (www.cdc.gov).

Operational Definition of a Functional Local Health Department

The National Association of County and City Health Officials (NACCHO) created the *Operational Definition of a Functional Local Health Department* in 2005 to develop standards based on the 10 EPHS and also consistent with the National Public Health Performance Standards Program (NPHPSP) (Fisher, 2016). The Operational Definition outlines what people in any community can reasonably expect from their local governmental public health presence to improve community and population health. It adds an additional forty-five capability standards spread throughout the 10 EPHS, such as "conduct or contribute expertise to periodic community health assessments" underneath the service *1. Monitor health status and understand health issues facing the community*. These standards, in addition to the 10 EPHS, are a step towards a more comprehensive model to be included in public health policy.

This model also allows for accountability metrics to be incorporated, such as through the PHAB's health department accreditation program and their *Standards and Measures*. NACCHO supports voluntary accreditation for health departments through PHAB and encourages the use of the Operational Definition as an accreditation preparation tool. Beyond the launch of the national accreditation program, NACCHO believes that the Operational Definition will continue to remain valuable in defining the work of local public health practice.

For more information, please view the *Operational Definition of a Functional Health Department* on the NACCHO website (www.naccho.org).

Foundational Public Health Services

The IOM Committee's third report in the *For the Public's Health* series, *Investing in a Healthier Future*, was focused toward the effects of decreased funding and difficulties in communicating the value of public health, leading toward identifying definitions for what 'public health' is. The report introduced the concept of a "*basic set or minimum package of public health services,*" further defining a set of "*foundational capabilities as an array of basic programs no health department can be without*" (Institute of Medicine, 2012). The IOM committee recommended this concept to improve upon the limitations of the Three Core Public Health Functions and 10 EPHS, and it created momentum for a model to be universally available at the local level and typically provided by governmental public health. These services are not required to be completed only by local government, but in partnership with state government, other local government jurisdictions (via cross-jurisdictional sharing) and private sector entities that provide public health services.

In 2013, the Public Health Leadership Forum obtained funding from the Robert Wood Johnson Foundation and contracted with RESOLVE, an independent, nonprofit organization, to explore recommendations offered within the IOM Committee's report series. RESOLVE drafted an initial model called *Defining and Constituting Foundational "Capabilities" and "Areas" Version 1 (V-1)*, often called the **Foundational Public Health Services (FPHS) model** or the **RESOLVE model** (RESOLVE, 2014). The RESOLVE model included both *Foundational Capabilities* (FCs), which are cross-cutting skills that need to be present in health departments everywhere for the health system to work anywhere, and *Foundational Areas* (FAs), which are substantive areas of expertise or program-specific activities essential for all health departments to protect the health of communities.

Following the publication of the RESOLVE model, the Public Health Accreditation Board (PHAB) has stewarded the FPHS framework as a national model for a minimum package of public health services (*The Foundational Public Health Services*, 2024). Following a 2022 update to the FPHS framework, adding 'Equity' as a FC and defining "Community-specific Services," the FPHS framework includes the following FCs and FAs (*The Foundational Public Health Services*, 2024):

Foundational Capabilities (FCs)

- *Assessment & Surveillance*
- *Community Partnership Development*
- *Equity*
- *Organizational Competencies*
- *Policy Development & Support*
- *Accountability & Performance Management*
- *Emergency Preparedness & Response*
- *Communications*

Foundational Areas (FAs)

- *Communicable Disease Control*
- *Chronic Disease & Injury Prevention*
- *Environmental Public Health*
- *Maternal, Child, & Family Health*
- *Access to & Linkage with Clinical Care*

Some states have incorporated its elements into their public health policy, often making additional modifications to the FPHS model's FCs, FAs and components defined underneath each service. This creates a great variation among public health models found within state public health policy and limits the model's ability to serve as a single national model. One additional limitation is due to the fact that it seems neither the U.S. DHHS nor CDC have officially accepted the FPHS model as a replacement of the 10 EPHS or as a tool to support delivering the 10 EPHS, in contrast to prior revitalizations following IOM recommendations. The CDC, however, has been a partner in efforts to define, constitute, and estimate costs of FPHS.

For more information, please view the *Foundational Public Health Services* on the PHAB website (https://phaboard.org/).

Public Health Services Models from Other States

There is considerable variation in both form and function of public health models in other states with no strong consistency among states in specific services to be in the domain of public health. A study was performed in 2016 in which minimum package elements from the IOM report and the RESOLVE model's framework were crosswalked across Washington, Ohio, Oregon, and five other states (Orr, 2017). It was found that the RESOLVE model was a common reference point for most models that had been identified, both being influenced by pre-existing state minimum package models and later influencing new state models (Orr, 2017). Versus the RESOLVE model, states ranged from having less than ten percent similarity to the model to almost ninety percent similarity with the average similarity of models hovering around fifty percent.

Appendix B – Scoping Review Query Metrics

Table 15. Scoping Review Query Metrics – *Descriptions of Queries*

Query ID	Query Note	Query	Source
I-WoS-01	*Individual search*; Years: 2000-19; Title: Systems Approach (w/o Systems Approach); Keyword Focus: Public Health Systems	(systems approach OR systems science OR systems thinking OR systems engineering OR systems analysis OR systems architecture OR systems design) OR (organization theory OR operations research OR operations research and management science OR operational research OR organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical systems thinking OR critical management science OR critical systems OR multi-method OR multimethodology) [title], United States AND governance AND service NEAR delivery AND ((public health OR population health OR population-based OR public policy OR community health) OR (public health system OR public health enterprise OR socio-technical OR sociotechnical) OR (local public health OR governmental public health)) from 2000 to 2019	Web of Science
I-WoS-02	*Individual search*; Years: 2000-19; Title: Public Health Systems; Keyword Focus: Systems Approaches (theory and organizational)	public health OR public policy OR population health OR community health OR population-based OR socio-technical OR sociotechnical [title], (organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical management OR critical systems) from 2000 to 2019	Web of Science
P-GS-01	*Paired search*; Years: 2000-19; Title: local public health OR public policy; Keyword Focus: Systems Approach (w/o system*), Systems Methods	local public health OR public policy [title], United States AND governance AND service* NEAR delivery AND ((systems approach OR systems science OR systems thinking OR systems engineering OR systems analysis OR systems architecture OR systems design OR systems theory OR control theory OR viability theory OR total systems intervention OR complexity theory) OR (organization theory OR operations research OR operations research and management science OR operational research OR organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical systems thinking OR critical management science OR critical systems OR multi-method OR multimethodology) OR (system dynamics OR agent-based OR machine learning OR network analysis OR systems modeling language OR SysML OR model-based systems engineering OR MBSE OR life cycle)) from 2000 to 2019	Google Scholar
P-GS-02	*Paired search*; Years: 2000-19; Title: Public Health Systems; Keyword Focus: Systems Approaches (theory and organizational) and Public Health Systems	public health OR public policy OR population health OR community health OR population-based OR socio-technical OR sociotechnical [title], (organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical management OR critical systems) AND (local public health OR governmental public health) from 2000 to 2019	Google Scholar

Query ID	Query Note	Query	Source
P-GS-03	*Paired search*; Years: 2000-19; Title: Systems Approach and Public Health; Keyword Focus: N/A	systems approach* AND public health [title] from 2000 to 2019	Google Scholar
P-GS-04	*Paired search*; Years: 2000-19; Title: Systems Approaches; Keyword Focus: Public Health	(systems approach OR systems science OR systems thinking OR systems engineering OR systems analysis OR systems design OR systems architecture) [title], ((public health OR population health OR population-based OR public policy OR community health) OR (public health system OR public health enterprise OR socio-technical OR sociotechnical) OR (local public health OR governmental public health)) from 2000 to 2019	Google Scholar
P-WoS-01	*Paired search*; Years: 2000-19; Title: local public health OR public policy; Keyword Focus: Systems Approach (w/o system*), Systems Methods	local public health OR public policy [title], United States AND governance AND service* NEAR delivery AND ((systems approach OR systems science OR systems thinking OR systems engineering OR systems analysis OR systems architecture OR systems design OR systems theory OR control theory OR viability theory OR total systems intervention OR complexity theory) OR (organization theory OR operations research OR operations research and management science OR operational research OR organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical systems thinking OR critical management science OR critical systems OR multi-method OR multimethodology) OR (system dynamics OR agent-based OR machine learning OR network analysis OR systems modeling language OR SysML OR model-based systems engineering OR MBSE OR life cycle)) from 2000 to 2019	Web of Science
P-WoS-02	*Paired search*; Years: 2000-19; Title: Public Health Systems; Keyword Focus: Systems Approaches (theory and organizational) and Public Health Systems	public health OR public policy OR population health OR community health OR population-based OR socio-technical OR sociotechnical [title], (organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical management OR critical systems) AND (local public health OR governmental public health) from 2000 to 2019	Web of Science
P-WoS-03	*Paired search*; Years: 2000-19; Title: Systems Approach and Public Health; Keyword Focus: N/A	systems approach* AND public health [title] from 2000 to 2019	Web of Science
P-WoS-04	*Paired search*; Years: 2000-19; Title: Systems Approaches; Keyword Focus: Public Health	(systems approach OR systems science OR systems thinking OR systems engineering OR systems analysis OR systems design OR systems architecture) [title], ((public health OR population health OR population-based OR public policy OR community health) OR (public health system OR public health enterprise OR socio-technical OR sociotechnical) OR (local public health OR governmental public health)) from 2000 to 2019	Web of Science

Table 16. Scoping Review Query Metrics – *Metrics for Queries*

P-GS-04	P-GS-03	P-GS-02	P-GS-01	I-WoS-02	I-WoS-01	Query ID
238	27	169	248	9	217	Papers
9333	638	6542	13168	29	2453	Citations
19	18	19	19	11	19	Years
491.21	35.44	344.32	693.05	2.64	129.11	Cites_Year
39.21	23.63	38.71	53.1	3.22	11.3	Cites_Paper
4621.5	507.27	3566.3	9271.23	7.62	943.04	Cites_Author
157.42	13.9	121.28	203.33	4.7	96.3	Papers_Author
2.17	2.67	1.83	1.54	3	3.66	Authors_Paper
36	8	29	41	3	24	h_index
95	25	80	114	5	44	g_index
31	8	23	34	2	20	hc_index
14.24	3.2	15.87	24.36	0.69	6.06	hI_index
26	6	24	36	1	14	hI_norm
1551.4	73.96	777.94	2068.36	4.46	429	AWCR
39.39	8.6	27.89	45.48	2.11	20.71	AW_index
730.7	54.79	424.26	1670.09	1.36	148.25	AWCRpA
84.18	23.54	71.39	100.92	4	31.84	e_index
24.85	5.25	22.2	34.58	0.75	14.7	hm_index
8/6/2019	8/6/2019	8/6/2019	8/6/2019	8/6/2019	8/6/2019	QueryDate
243.23	28.18	187.7	487.95	0.69	49.63	Cites_Author_Year
1.37	0.33	1.26	1.89	0.09	0.74	hI_annual
89.8	96.9	90.8	90.1	86.2	64.8	h_coverage
98.7	100	99.2	99.1	93.1	79.2	g_coverage
24	1	14	32	0	12	star_count
2000	2001	2000	2000	2008	2000	year_first
2019	2019	2019	2019	2018	2019	year_last
9333	638	6542	13168	29	2453	ECC

P-WoS-04	P-WoS-03	P-WoS-02	P-WoS-01	Query ID
309	11	73	83	Papers
4441	61	596	1724	Citations
19	15	17	19	Years
233.74	4.07	35.06	90.74	Cites_Year
14.37	5.55	8.16	20.77	Cites_Paper
1931.29	29.82	175.42	1178.93	Cites_Author
132.98	4.36	24.76	49.53	Papers_Author
3.8	3.73	4.08	2.4	Authors_Paper
31	4	15	19	h_index
58	7	21	41	g_index
29	4	13	14	hc_index
7.88	1.45	3.41	11.28	hI_index
19	2	7	16	hI_norm
752.72	12.11	162.78	220.17	AWCR
27.44	3.48	12.76	14.84	AW_index
298.99	4.77	41.32	132.83	AWCRpA
42.86	6.16	13.15	33.59	e_index
19.57	2.53	7.33	14.75	hm_index
8/6/2019	8/6/2019	8/6/2019	8/6/2019	QueryDate
101.64	1.98	10.31	62.04	Cites_Author_Year
1	0.13	0.41	0.84	hI_annual
63	88.5	66.8	86.4	h_coverage
77.4	98.4	76.7	97.6	g_coverage
25	0	3	5	star_count
2000	2004	2002	2000	year_first
2019	2019	2019	2019	year_last
4441	61	596	1724	ECC

Appendix C – Scoping Review Methodology

PROSPERO Elements

<table>
<tr><td>Review Title</td><td colspan="4">Application of systems approaches in governmental public health</td></tr>
<tr><td>Start Date</td><td>08/01/2019</td><td colspan="2">Completion Date</td><td>4/15/2020</td></tr>
<tr><td rowspan="3">Stage of Review</td><td colspan="2">☐ Preliminary Searches</td><td colspan="2">☐ Piloting Study Selection</td></tr>
<tr><td colspan="2">☐ Eligibility Screening</td><td colspan="2">☐ Data Extraction</td></tr>
<tr><td colspan="2">☐ Quality Assessment</td><td colspan="2">☒ Data Analysis</td></tr>
<tr><td>Review Team</td><td colspan="4">Reviewer 1
Reviewer 2
Reviewer 3</td></tr>
<tr><td>Funding/Sponsoring</td><td colspan="4">Self-funded dissertation research.</td></tr>
<tr><td>Conflicts of Interest</td><td colspan="4">N/A</td></tr>
<tr><td>Collaborators</td><td colspan="4">Potentially other committee members</td></tr>
</table>

Investigation of how public health systems may be designed for their governance or mechanisms of service delivery. This study is somewhat similar to but distinct from two other registered reviews: CRD42016049967 (our study focuses on the design) and CRD42017065920 (our study focuses on public health and public policy).

Methods

Research Questions

- **Main**: How may a systems approach toward design of governance structure and service delivery mechanisms of a public health system improve service delivery? **(“*application*”)**
- **Outcome of Interest**: Perceived effectiveness of systems approaches toward governance and service delivery.

Search Protocol

The tool "Publish or Perish" (PoP) will be used with Google Scholar and Web of Science to complete keyword searches across search terms. Search terms will vary across searches but each will include variations of "public health" and "systems approaches". Google Scholar will obtain both gray and peer reviewed literature on the subjects and Web of Science will return peer-reviewed literature. Search years will be 2000-2019, written in English, with strong preference to United States local public health systems. The review will likely progress agnostic to the type of study though randomized trials will offer higher quality evidence toward the research question. The intended context is public health or public policy (particularly local government and ideally within the United States).

There is no singular agreed upon definition for "systems approach", though it may include systems design/engineering, systems analysis, systems thinking/science, etc. Review will aim to include studies which contribute to this broad definition of systems approach. Potential comparators are other approaches toward designing governance and service delivery for public health and public policy.

Search Criteria

Searches to be performed using "Publish or Perish" (PoP) version 6 via keyword search to obtain results for each research question.

Search Parameters

- **Time Period**: 2000-2019
- **Language (*where available*)**: English only
- **Location (*where available*)**: any United States ("Western" policy systems)
    - *"United States", "local government", "state government", "county government"*
        - *Non-US-based studies were found in search output, but most were screened out. Several UK-based studies were retained as they were highly relevant.*
- Type of Material
    - ***Peer-Reviewed***: *reviews, analytic essays, summary/synthesis*
    - ***Gray Literature***: *organizational reports, environmental scans, policy statements*

Keyword Search (PoP)

- Keyword List

  The main research question is split into its specific words or phrases. These topics are further split into branches which group synonymous terms together. Some priority terms are shaded while synonymous terms are highlighted.

  - *"systems approach" (needs to be present in all):*
    - *system*, "systems approach", "systems science", "systems thinking", "systems engineering", "systems analysis", "systems architecture", "systems design", "systems theory", "control theory", "viability theory", "total systems intervention", "complexity theory",*
    - *"organization theory", "operations research", "operations research and management science", "operational research", "organizational cybernetics", "management cybernetics", "viable system theory", "autonomous agency theory", "cultural agency theory", sociocybernetics, "service science", "critical systems thinking", "critical management science", "critical systems", "multi-method", "multimethodology",*
    - *holistic, principles, heuristic*, feedback, abstraction, parsimon*,*
  - *"design":*
    - *design*, engineer*, plan*, development, moderniz*, architect*, specif*, praxis, model*, simulat*, optim*, prototype*,*
    - *"system dynamics", "agent-based", "machine learning", "network analysis", "systems modeling language", SysML, "model-based systems engineering", MBSE, "life cycle",*
  - *"governance structure":*
    - *authori*, "decision-making", decisionmaking, "policy-making", policymaking, govern*, advis*, "organizational control",*
    - *"top executive", board, "board of health", "boards of health", commission*, appoint*, elect*, council*, "viability kernel",*
    - *agenc*, partnership, organization, "umbrella agency", "super-agency", superagency, "free-standing", freestanding,*

        - *centraliz*, decentraliz*, independent, mixed, federalism, federation, "federation of systems", "system of systems", "systems of systems",*
        - *government*, jurisdiction*, border, federal, national, state, district, "special district", local, county, tribal,*
        - *structure*, merg*, consolidate*, "public private", quasi*, regionalization, integrat*, hybrid,*
    - *"service delivery mechanism":*
        - *service*, model, framework, "public health services", essential, EPHS, core, foundational, FPHS, "minimum package", intervention*, capabilit*,*
        - *deliver*, "cross-jurisdictional", interdependen*, "supply chain", "supply chain management"*
        - *unit*, agent, department, coalition, staff*, holon, holarchy*,*
        - *contract*, affermage, agreement, shar*, colocat*, co-locat*, coordinat*, network*, cooperat*, differentiat*, align*,*
    - *"public health" (strong preference for "public health" but need to expand to public policy to attain more hits):*
        - *"public health", "population health", "population-based", "public policy", "community health",*
        - *"public health system", "public health enterprise", "socio-technical", sociotechnical,*
        - *"local public health", "governmental public health",*
- MeSH Terms (did not use MeSH searching)
    - *Systems Engineering*
        - *("Systems Theory"[Mesh])*
        - *("Systems Analysis"[Mesh])*
    - *Public Health*
        - *("Public Health"[Mesh])*
        - *("Public Health Practice"[Mesh])*
        - *("Public Health Administration"[Mesh])*
        - *("Public Health Systems Research"[Mesh])*

            - *("Policy"[Mesh]")*
            - *("Organizational Policy"[Mesh])*
            - *("Public Policy"[Mesh])*
            - *("Policy Making"[Mesh])*
            - *("Health Policy"[Mesh])*
        - *Service Delivery*
            - *("Organizations"[Mesh])*
            - *("Government"[Mesh])*
            - *("Contracts"[Mesh])*
            - *("Contract Services"[Mesh])*
            - *("Public-Private Sector Partnerships"[Mesh])*
            - *("Multi-Institutional Systems"[Mesh])*
            - *("Hospital Shared Services"[Mesh])*
            - *("Organization and Administration"[Mesh])*
            - *("Centralized Hospital Services"[Mesh])*
- New Terms Identified Following Searches (*did not add as search terms*)
    - <u>*Chaord*</u>
    - <u>*Chaordic Systems Thinking (CST)*</u>
- Exclusion Criteria (subjective, separate from the eligibility criteria)
    - *Article Subject*
        - *Article subject is not within the public policy domain*
        - *Article subject is another non-Western country (e.g., public middle schools in Morocco)*
        - *Article subject is not system of public partners (e.g., water distribution system, clinical trial, social network, internal hospital system)*
            - A network of water suppliers and network governance, however, includes a system of public partners.
    - *Systems Application*

        - *Systems application is information technology or information system (e.g., new computer system, e-consultation)*
        - *Systems application is modeling or simulation of an event (e.g., modeling flood risk, emergency DSS)*
        - *Systems application is workplace quality or safety (e.g., workplace safety, healthcare quality or patient safety)*
        - *Systems application is epidemiology or intervention (e.g., agent-based modeling of epidemic)*
    - *Other*
        - *Consider that if the material Type (Column M) is "Book", it is unlikely that a quality finding may be found (not peer-reviewed, text may appear anywhere)*
        - *.Governance of an information system is not of interest*
- Search Strategies (total of 10 different searches)
    - *Test Searches*
        - ***Test_WoS-P-01:*** ***Years***: *[any];* ***All***: *[(systems approach OR systems science OR systems thinking) AND (govern* OR board OR policy*) AND (service delivery OR interdependen*)];* ***Title***: *[public health, systems];* ***Any***: *[N/A];* ***None***: *[N/A];* ***Phrase***: *[N/A]*
            - 6 papers (2008-2017), 56 citations
        - ***Test_GS-P-01***: ***Years***: *[any];* ***All***: *[(systems approach OR systems science OR systems thinking) AND (govern* OR board OR policy*) AND (service delivery OR interdependen*)];* ***Title***: *[public health, systems];* ***Any***: *[N/A];* ***None***: *[N/A];* ***Phrase***: *[N/A]*
            - 15 papers (1996-2018), 536 citations
    - *Google Scholar (via PoP)*
        - ***P-GS-01:*** ***Years***: *[2000-2019];* ***All***: *[United States AND governance AND service* NEAR delivery AND ((systems approach OR systems science OR systems thinking OR systems engineering OR systems analysis OR systems architecture OR systems design OR systems theory OR control theory OR viability theory OR total systems intervention OR complexity theory) OR (organization theory OR operations research OR operations research and management science*

*OR operational research OR organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical systems thinking OR critical management science OR critical systems OR multi-method OR multimethodology) OR (system dynamics OR agent-based OR machine learning OR network analysis OR systems modeling language OR SysML OR model-based systems engineering OR MBSE OR life cycle))]; **Title**: [local public health OR public policy]; **Any**: [N/A]; **None**: [N/A]; **Phrase**: [N/A]*

    - 248 papers (2000-2019), 13,168 citations

- ***P-GS-02:*** ***Years**: [2000-2019]; **Title**: [public health OR public policy OR population health OR community health OR population-based OR socio-technical OR sociotechnical]; **All**: [(organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical management OR critical systems) AND (local public health OR governmental public health)] ; **Any**: [N/A]; **None**: [N/A]; **Phrase**: [N/A]*
    - 169 papers (2000-2019), 6,542 citations
- ***P-GS-03:*** ***Years**: [2000-2019]; **Title**: [systems approach* AND public health]; **All**: [N/A] ; **Any**: [N/A]; **None**: [N/A]; **Phrase**: [N/A]*
    - 27 papers (2001-2019), 638 citations
- ***P-GS-04:*** ***Years**: [2000-2019]; **Title**: [(systems approach OR systems science OR systems thinking OR systems engineering OR systems analysis OR systems design OR systems architecture)]; **All**: [((public health OR population health OR population-based OR public policy OR community health) OR (public health system OR public health enterprise OR socio-technical OR sociotechnical) OR (local public health OR governmental public health))] ; **Any**: [N/A]; **None**: [N/A]; **Phrase**: [N/A]*
    - 238 papers (2000-2019), 9,333 citations

- *Web of Science (via PoP)*
    - ***P-WoS-01:*** ***Years**: [2000-2019]; **Title**: [local public health OR public policy]; **All**: [United States AND governance AND service* NEAR delivery AND ((systems approach OR systems*

science OR systems thinking OR systems engineering OR systems analysis OR systems architecture OR systems design OR systems theory OR control theory OR viability theory OR total systems intervention OR complexity theory) OR (organization theory OR operations research OR operations research and management science OR operational research OR organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical systems thinking OR critical management science OR critical systems OR multi-method OR multimethodology) OR (system dynamics OR agent-based OR machine learning OR network analysis OR systems modeling language OR SysML OR model-based systems engineering OR MBSE OR life cycle))]

  - 83 papers (2000-2019), 1,724 citations

- ***I-WoS-01*:** ***Years**: [2000-2019]; **Title**: [(systems approach OR systems science OR systems thinking OR systems engineering OR systems analysis OR systems architecture OR systems design) OR (organization theory OR operations research OR operations research and management science OR operational research OR organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical systems thinking OR critical management science OR critical systems OR multi-method OR multimethodology)]; **All**: [United States AND governance AND service NEAR delivery AND ((public health OR population health OR population-based OR public policy OR community health) OR (public health system OR public health enterprise OR socio-technical OR sociotechnical) OR (local public health OR governmental public health))]*

  - 217 papers (2000-2019), 2,453 citations

- ***P-WoS-02*:** ***Years**: [2000-2019]; **Title**: [public health OR public policy OR population health OR community health OR population-based OR socio-technical OR sociotechnical]; **All**: [(organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science*

OR critical management OR critical systems) AND (local public health OR governmental public health)]

- 73 papers (2002-2019), 596 citations

- ***I-WoS-02:*** ***Years****: [2000-2019];* ***Title****: [public health OR public policy OR population health OR community health OR population-based OR socio-technical OR sociotechnical];* ***All****: [(organizational cybernetics OR management cybernetics OR viable system theory OR autonomous agency theory OR cultural agency theory OR sociocybernetics OR service science OR critical management OR critical systems)]*
    - 9 papers (2008-2019), 29 citations
- ***P-WoS-03:*** ***Years****: [2000-2019];* ***Title****: [systems approach* AND public health];* ***All****: [N/A]*
    - 11 papers (2004-2019), 61 citations
- ***P-WoS-04:*** ***Years****: [2000-2019];* ***Title****: [(systems approach OR systems science OR systems thinking OR systems engineering OR systems analysis OR systems design OR systems architecture)];* ***All****: [((public health OR population health OR population-based OR public policy OR community health) OR (public health system OR public health enterprise OR socio-technical OR sociotechnical) OR (local public health OR governmental public health))]*
    - 309 papers (2000-2019), 4,441 citations

Review Protocol

Citations will first undergo a preliminary relevance assessment (title and/or abstract against the research question); two reviewers plus one to resolve conflicts. Full-text articles will be obtained for relevant citations. Full-text articles will then be appraised for eligibility according to three criteria: (i) Criteria 1: document discusses at least one “systems approach”; (ii) Criteria 2: document applies systems approach(es) to public policy domain; and (iii) Criteria 3: document discusses application of systems approach(es) to change governance OR service delivery. Two reviewers plus one to resolve conflicts.

Data extraction will utilize a spreadsheet with the following extraction columns: i) Standard Elements: Author, year, journal, etc.; ii) SE Elements: Systems Approach(es), Classification(s); iii) Application Elements: Public Policy Domain, Governance Change, Service Delivery Change; and iv) Summary Elements: Outcome(s), Conclusion/Implication(s), Quotes, Other Notes.

Retrieving Citations and Screening

- Reviewers (1–3)
  - ***Reviewer 1****: relevance screening; eligibility review; data extraction/synthesis/analysis; drafting*
  - ***Reviewer 2****: relevance screening; eligibility conflict resolution; data extraction/synthesis/analysis; drafting*
  - ***Reviewer 3:*** *relevance screening conflict resolution; eligibility review; data extraction/synthesis/analysis; drafting*
- **Document Search** (according to above)
  - ***Remove*** *any duplicates*
- **Relevance Assessment** (title and/or abstract against research question)
  - ***Retain*** *if appropriate – retrieve full article*
  - ***Remove*** *if inappropriate – document why removed upon disagreement*

Critical Appraisal of Evidence

- Eligibility Appraisal (full article)
  - ***Retain*** *if meeting eligibility criteria*
    - *Eligibility Criteria*
      - **Criteria 1**: document discusses at least one "systems approach"
        - *Examples: systems analysis, systems engineering, organizational cybernetics*

        - **Criteria 2**: document applies systems approach(es) to public policy domain
            - *Examples: health policy, health administration, health systems research*
            - *Strong preference for applications in Public Health.*
        - **Criteria 3**: document discusses application of systems approach(es) to change governance OR service delivery
            - *Governance: decision-making, governing structure, legislation*
            - *Service Delivery: independent delivery, contracted agent, shared delivery*
    - ***Remove*** *if not meeting criteria – document which criteria may be missing*
- Quality Appraisal of Documents (not performed due to study design)
    - *As the present review is not a clinical study or comparison of practice interventions, the studies are of a heterogeneous nature, and the focus is on prevalence of systems approaches not investigation into their efficacy, additional quality appraisal was not deemed to be warranted.*

Data Collection Process

- Data Extraction (spreadsheet):
    - *Standard Elements (PoP citation output): Author, Year, Publisher, etc.*
    - *SE Extraction: Systems Approach, Classification*
    - *Policy Extraction: Policy Domain, Governance, Service Delivery*
    - *Study Extraction: Methods, Results, Discussion/Conclusion*
    - *Other: Quotes, Other*
- Analysis Categories for Theming (spreadsheet):
    - *Theoretical Categorizations*

      Theoretical Domain ← Theory ← Sub-Theory
        - *Dissemination & Implementation Science*
            - Diffusion of Innovation Theory

- *Social Science*
  - Economic Theories
  - Political Theories
    - *Discourse Theory*
    - *Rational Theory*
  - Sociological Theories
    - *Evaluation Theory*
    - *Social Shaping Theory*
    - *Theory of Reasoned Action*
- *Systems Science*
  - Chaos Theory
  - Complexity Theories
    - *Autopoiesis*
  - Cybernetics Theories
    - *Control Theory*
    - *Decision Theory*
    - *Information Theory*
    - *Socio-technical Systems Theory*
  - General Systems Theory
  - Organizational Theories
    - *Dimensional Publicness Theory*
- *N/A*

○ ***Analytical Representation***: *Hypothesis, Recommendation, Model (analytical, descriptive, hybrid), Network Map, Simulation, N/A*

○ ***Systems Methodology***: *Soft, Hard, Pragmatic*

○ ***Public Policy Domain***

Sector ← Area

- *Public Services*
    - Planning & Development
    - Public Administration
    - Public Health
    - Public Policy
- *Health Care*
    - Health Center
    - Hospital
- *N/A*

- ***Governance Function (Carlson et al)**: Non-Specific (any function), Continuous Improvement, Legal Authority, Oversight, Partner Engagement, Policy Development, Resource Stewardship, N/A*
- ***Governing Boundaries**: Non-Specific (any boundary), Coalition/Partnership, Internal (all), Internal (agency), Internal (departments), Jurisdictional, Multi-Jurisdictional, Multi-Sectoral, Regionalization, N/A*
- ***Service Delivery Mechanism**: Non-Specific (any form), Agent (CJS), Agent (CSC), Independent, Internal (D&I), Joint/Shared, N/A*

Risk of Bias Considerations (via Cochrane)

Team of 3 researchers has come up with approach under guidance of 6-member advisory committee (of which 2 of committee are members). Titles and abstracts (screening) will be reviewed by 2 researchers independently, with 1 resolving screening disagreements as needed. Full-text articles (eligibility) will be reviewed by 2 researchers independently, with 1 resolving eligibility disagreements as needed.

This review will consider peer reviewed literature and gray/white literature (practice-based materials from state and local governments). We will detail both in the review so the reader can consider quality differences as part of their overall read. Team anticipates that 1) use of screening and eligibility criteria and 2) no necessity for meta-analysis or other quantitative assessment makes further quality appraisal unnecessary.

- Rapid Review Process (FYI for manuscript)
- Types
  - ***Selection Bias**: biased allocation to intervention (sequence generation, allocation concealment)*
  - ***Performance Bias**: knowledge of allocated interventions by participants/personnel of study*
  - ***Detection Bias**: knowledge of allocated interventions by outcome assessors (blinding)*
  - ***Attrition Bias**: loss by amount/nature/handling of incomplete outcome data*
  - ***Reporting Bias**: selective outcome reporting*
- Typical
  - ***If only 1 reviewer selects studies**: less transparency and reproducibility*
  - ***If only 1 reviewer extracts data**: may increase errors*
  - ***If gray literature excluded**: may exclude unpublished data/negative results*
  - ***If excluding older articles**: may exclude significant results*

Data Synthesis and Analysis (simplified for this manuscript)

Synthesis of aggregate data will be through tabulation of key aspects of the included studies with a narrative description of characteristics across studies. Meta-analysis may be conducted on a subset of studies having quantitative findings, though this may be unlikely. Heterogeneity of study designs is anticipated so it is difficult at this stage to predict what subgroups or subsets may be identified. This will become more apparent after initial data extraction.

- Examples
    - *Principle Summary Measures (risk ratio, difference in means)*
    - *Methods to Synthesize Results (aggregation; quantitative or narrative)*
        - *Unlikely that resultant studies will be homogenous*
            - They were not; analysis performed by descriptive frequency
    - *Additional Analysis Methods (sensitivity/subgroup analysis, meta-regression)*

Appendix D – Scoping Review Results Summary

Table 17. Overview of Articles

1.	**A Vining: What Is Public Agency Strategic Analysis (PASA) and How Does It Differ from Public Policy Analysis and Firm Strategy Analysis?**
a.	Public Agency Strategic Analysis (PASA); Classifications: Strategic Analysis
b.	Public Policy: Gov. (Decision-making); SD (Internal and External)
c.	*Includes some discussion on service delivery*
2.	**Alexander Dawoody: The Nexus as a Complexity Model for Public Policy**
a.	Nexus Model; Classifications: Agent-Based Model, Network Analysis, System Dynamics
b.	Public Policy: Gov. (Decision-making); SD (N/A)
c.	*Nexus Model: flattens the hierarchal structure into a loop of interconnected forces/agents, whereby each agent interacts and collaborate within other agents in the network through symbiotic relationships; presents as a complex and multi-dimensional loop of associations between autonomous agents who are interconnected within a network and respond to environmental changes by experiencing phase-shifts, emergence, self-organization, and collapse.*
3.	**Ana V. Diez Roux: Complex Systems Thinking and Current Impasses in Health Disparities Research**
a.	Complex Systems Analysis (general); Classifications: Complex Systems Approaches
b.	Public Health: Gov. (Decision-making); SD (N/A)
c.	*Provides a general endorsement for systems science; much focus placed on the SDM of health disparities*
4.	**Ana V. Diez Roux: Health in cities: is a systems approach needed?**
a.	Complex Systems Analysis (general); Classifications: Complex Systems Approaches
b.	Public Health: Gov. (Decision-making); SD (N/A)
c.	*Great overview of systems approaches and benefits*
5.	**B. E. White: A Complex Adaptive Systems Engineering (CASE) Methodology. The Ten-Year Update**
a.	Complex Adaptive Systems Engineering (CASE), System Dynamics Modeling (SDM); Classifications: Complex Systems Theory, System Dynamics
b.	Public Policy: Gov. (Intraorganizational, Interorganizational); SD (Internal and External)
c.	*Complex SE approach to governance*
6.	**Barry Bozeman: What Organization Theorists and Public Policy Researchers Can Learn from One Another: Publicness Theory as a Case-in-Point**
a.	Dimensional Publicness Theory; Classifications: Public Policy, Organization Theory
b.	Public Policy: Gov. (Interorganizational, Public & Private); SD (N/A)
c.	*Primer on reciprocation (or lack thereof) between public policy and organization theory, then focus on "dimensional publicness"*
7.	**BD Jones, FR Baumgartner: A model of choice for public policy**
a.	General Punctuation Hypothesis; Classifications: Policy-Making Model
b.	Public Policy: Gov. (Decision-making); SD (Internal and External)
c.	*Modeling decision-making over time*
8.	**Brian W. Head, John Alford: Wicked Problems: Implications for Public Policy and Management**
a.	Systems Thinking, Complexity Science; Classifications: Complexity Theory, Policy Network Theory, Resource Dependency Theory, Exchange Theory
b.	Public Policy: Gov. (Intraorganizational & Interorganizational, Public & Private); SD (External)
c.	*Contrast between traditional and contemporary systems*

9. Charlan D. Kroelinger, Kristin M. Rankin, David A. Chambers, Ana V. Diez Roux, Karen Hughes, Violanda Grigorescu: Using the Principles of Complex Systems Thinking and Implementation Science to Enhance Maternal and Child Health Program Planning and Delivery
a. Complex Systems Thinking, Implementation Science; Classifications: Complex Systems, Implementation Science
b. Public Health: Gov. (N/A); SD (N/A)
c. General discussion on applicatiof complex systems and implementation science
10. Christina Seidel: The application of life cycle assessment to public policy development
a. Life Cycle Assessment (LCA); Classifications: Systems Design
b. Public Policy: Gov. (Decision-making); SD (N/A)
c. Systems design approach
11. D Hunter, N Perkins: Partnership working in public health: the implications for governance of a systems approach
a. Complex Systems Thinking (minimal focus); Classifications: Systems Thinking
b. Public Health: Gov. (Local/Regional Partnerships); SD (Partnerships)
c. UK-focused; some relevance to my research
12. D Young, R Borland, K Coghill: An actor-network theory analysis of policy innovation for smoke-free places: understanding change in complex systems
a. Actor-Network Theory (ANT); Classifications: Loose hybrid of ABMs & SDMs
b. Public Policy: Gov. (Decision-making); SD (External)
c. Combines ABM and SDM with elements of network analysis
13. Douglas A. Luke, Katherine A. Stamatakis: Systems Science Methods in Public Health: Dynamics, Networks, and Agents
a. SD, ABM, NA; Classifications: Models
b. Public Health: Gov. (N/A); SD (N/A)
c. Consider using Table 1
14. Edward H. Ip, Hazhir Rahmandad, David A. Shoham, Ross Hammond, Terry T. -K. Huang, Youfa Wang, Patricia L. Mabry: Reconciling Statistical and Systems Science Approaches to Public Health
a. Multi (ABM, SDM); Classifications: Multi (ABM, SDM)
b. Public Health (non-specific): Gov. (N/A); SD (N/A)
c. Marriage between SS approaches and statistical approaches
15. Emily F. Gates: Making sense of the emerging conversation in evaluation about systems thinking and complexity science
a. Multiple mentioned: Causal Loop Diagrams (CLD), Systems Dynamics Modeling (SDM), Agent-Based Modeling (ABM), soft systems methods (SSM), social network analysic (NA), critical systems heuristics (CSH), Viable Systems Model (VSM), second-order cybernetics, dialogic design science; Classifications: Systems Thinking and Complexity Science (STCS)
b. Public Policy: Gov. (Evaluation); SD (N/A)
c. SR of STCS (similar to this lit review); focus is specifically on evaluation
16. Eric Silverman: Bringing ALife and Complex Systems Science to Population Health Research
a. ALife; Classifications: Artificial Life Models
b. Public Health: Gov. (N/A); SD (N/A)
c. Not a strong article
17. Gemma Carey, Eleanor Malbon, Nicole Carey, Andrew Joyce, Brad Crammond, Alan Carey: Systems science and systems thinking for public health: a systematic review of the field
a. Multi (SR output); Classifications: Multi (SR output)
b. Public Health: Gov. (Decision-making); SD (N/A)
c. SR of Systems science and systems thinking (similar to this lit review)
18. Guruprasad Madhavan, Charles E. Phelps, William B. Rouse, Rino Rappuoli: Vision for a systems architecture to integrate and transform population health

a.	Systems Architecture; Classifications: Systems Architecture
b.	Public Heath: Gov. (Interorganizational, public and private); SD (Partnerships)
c.	*Great means of organizing PH*
19.	**I. David Wheat: What Can System Dynamics Learn From the Public Policy Implementation Literature?**
a.	System Dynamics Models; Classifications: System Dynamics
b.	Public Policy: Gov. (Decision-making); SD (N/A)
c.	*Focus on designing policy structure; minimal relevance*
20.	**Jacqueline Merrill, Michael Caldwell, Maxine L. Rockoff, Kristine Gebbie, Kathleen M. Carley, Suzanne Bakken: Findings from an organizational network analysis to support local public health management**
a.	Network Analysis (Organizational Risk Analyzer); Classifications: Network Analysis (intraorganizational)
b.	Public Health: Gov. (Intraorganizational); SD (Internal)
c.	*Great example of research interest; collaborative analysis of NA between staff & researchers*
21.	**Jessica G. Burke, Kristen Hassmiller Lich, Jennifer Watling Neal, Helen I. Meissner, Michael Yonas, Patricia L. Mabry: Enhancing Dissemination and Implementation Research Using Systems Science Methods**
a.	SD, ABM, NA; RE-AIM framework; Classifications: Complex System Modeling
b.	Public Policy: Gov. (Intraorganizational); SD (Dissemination & Implementation (D&I))
c.	*Provides an overview of systems approaches (SDM, ABM, NA) with case studies*
22.	**JM Bauer, PM Herder: Designing socio-technical systems**
a.	Socio-Technical Systems Design (constrained optimization, systems approaches, complexity theory); Classifications: Mathematical Optimization, Complexity Theory
b.	Public Policy: Gov. (Intraorganizational, Interorganizational); SD (Internal & External)
c.	*There is just too much to note; will need to regard this article specially when developing the write-up*
23.	**Julie M. Kapp, Eduardo J. Simoes, Anne DeBiasi, Steven J. Kravet: A Conceptual Framework for a Systems Thinking Approach to US Population Health**
a.	Malcolm Baldridge Framework (modified); Classifications: Quality Improvement (system)
b.	Public Health: Gov. (Interorganizational, public and private; Outcomes-focused management); SD (N/A)
c.	*While some articles begin to introduce these concepts (Atun, 2012; Carey et al., 2015; Diez Roux, 2011; Leischow and Milstein, 2006; Leischow et al., 2008; Peters, 2014; Peters, 2014), they do not introduce methodological innovations as is needed (Cabrera, 2006) and are less applied in their approach. What is needed is a model or a framework of systems thinking, not [another] theory of systems (Cabrera, 2006).*
24.	**Juliet Sims, Manal J. Aboelata: A System of Prevention: Applying a Systems Approach to Public Health**
a.	System of Prevention (Sims & Aboelata); Classifications: Conceptual Framework
b.	Public Health: Gov. (Interorganizational); SD (Some elements of collaboration (CJS and CSC))
c.	*Similar title to my work*
25.	**Kristen Hassmiller Lich, Jennifer Brown Urban, Leah Frerichs, Gaurav Dave: Extending systems thinking in planning and evaluation using group concept mapping and system dynamics to tackle complex problems**
a.	Group Concept Mapping (GCM), System Dynamics Modeling (SDM); Classifications: Systems Thinking, System Dynamics
b.	Public Policy: Gov. (Interorganizational); SD (External)
c.	*Intro provides a round-up of contemporary systems thinking research.* *Concept Systems Global MAX software for concept mapping.*
26.	**M Schwaninger, S Ulli-Beer…: Policy analysis and design in local public management a system dynamics approach**
a.	System Dynamics Models; Classifications: System Dynamics

b.	N/A: Gov. (N/A); SD (N/A)
c.	*Switzerland context; not much here*
27.	**Marta Lenartowicz: Financing organizational changes from without: A valid instrument or a costly illusion of strategic public policy?**
a.	Autopoietic Organizational System; Classifications: "Second-Order Systems Thinking"; Organizational Theory
b.	Public Policy (PH example): Gov. (Intraorganizational focus, Interorganizational discussion); SD (Internal)
c.	*Strong background discussion on systems concepts and evolution over time (e.g., "first-order" systems thinking vs "second-order" systems thinking)*
28.	**Mary E. Northridge, Sara S. Metcalf: Enhancing implementation science by applying best principles of systems science**
a.	Systems Modeling; Classifications: Complexity Theory; Implementation Science
b.	Health Care: Gov. (Intraorganizational); SD (Dissemination & Implementation (D&I))
c.	*Not a strong article*
29.	**Navid Ghaffarzadegan, John Lyneis, George P. Richardson: How small system dynamics models can help the public policy process**
a.	System Dynamics Models; Classifications: System Dynamics
b.	Public Policy: Gov. (Decision-making); SD (External)
c.	*Argument for simplicity in SDM/CLD*
30.	**Nicholas P. Patorniti, Nicholas J. Stevens, Paul M. Salmon: A systems approach to city design: Exploring the compatibility of sociotechnical systems**
a.	Socio-Technical Systems Design; Classifications: Socio-Technical Systems
b.	City Planning: Gov. (Intergovernmental); SD (Internal and External)
c.	*City Design*
31.	**Philip Haynes: Understanding the influence of values in complex systems-based approaches to public policy and management**
a.	Complex Systems; Classifications: Complex Systems Theory
b.	Public Policy: Gov. (Decision-making); SD (N/A)
c.	*Discussion on values in decision-making*
32.	**Robin C. Purshouse, Alan Brennan, John Holmes, Petra S. Meier: Commentary on Apostolopoulos et al. (2018): Systems and complex systems approaches for public health planningback to the future?**
a.	System Dynamics Models; Classifications: System Dynamics
b.	Public Health: Gov. (N/A); SD (N/A)
c.	*The referenced articles relate to alcohol abuse prevention and are not very closely related to my research focus.*
33.	**WM Trochim, DA Cabrera, B Milstein, RS Gallagher, SJ Leischow: Practical challenges of systems thinking and modeling in public health**
a.	Cluster Mapping; Classifications: Concept Mapping
b.	Public Health: Gov. (N/A); SD (N/A)
c.	*Discussions on utility of cluster mapping*
34.	**Y Bar-Yam: Improving the effectiveness of health care and public health: A multiscale complex systems analysis**
a.	Multiscale Analysis, Complexity Profile; Classifications: Information Theory
b.	Public Health, Health Care: Gov. (Intraorganizational & Interorganizational, Public & Private); SD (Internal & External)
c.	*Complexity scale as an analytic tool to understand role of organizational structure in organizational effectiveness. Complexity Profile (complexity as function of scale): To contrast 2 extreme possibilities, a system containing many individuals can be organized to perform a large number of unique (fine-scale) tasks, or a single largescale task. This illustrates a fundamental trade-off in organizational structure and function.*

Analogy of national healthcare finance to fluid flow (turbulence caused by growth of managed care, physician cooperatives, reporting/billing - particularly mergers and consolidations) *Concerns with reciprocal communication following separation*

Table 18. Notable Quotes from Articles

01 - A Vining
See Vining
02 - Alexander Dawoody
N/A
03 - Ana V. Diez Roux
Complex systems typically include heterogeneous agents at various levels, contact structures between agents, adaptation, nonlinear dynamics, and stochasticity. These features lead to the emergence of patterns at various scales. Although feedback, dependencies, and emergent patterns may characterize virtually all population health problems, they may be especially important in health disparities. The systems nature of health disparities may explain their persistence and robustness across different health outcomes and over time, and their resistance to interventions. The model itself represents a complex hypothesis about the fundamental processes that are involved. Even if they do not provide definitive answers, modeling approaches also allow thoughtful initial exploration of the plausible impacts of policies and interventions. The utility of systems modeling to integrate and make the best use possible of existing data, identify crucial data gaps, and explore processes in the context of limited data are important benefits of these approaches in health disparities research.
04 - Ana V. Diez Roux
As urban populations have grown, the health issues faced by city residents have expanded beyond the traditional urban health concerns linked to infectious diseases and toxic environmental exposures to also encompass chronic diseases The recent emphasis on multilevel approaches to research and intervention in population health has highlighted the ways in which a range of policies – and more generally many of the ways in which we organize or fail to organize ourselves as a society – can have important health consequences. For example, over 40 years ago, Forrester, often described as one of the founders of system dynamics, used a growth model to generate the life cycle of an urban area from its founding through its decay 250 years later. He also used systems modeling to explore how various policies (related to employment, housing, and industry) might affect the evolution of a depressed city over the next 50 years 3. More recently, in his book The New Science of Cities, Batty 4 argues that to understand cities we must view them as systems of networks and flows, and uses the concepts and tools of complex systems to discuss the structure of cities and how they function. Arguably, identifying the most appropriate intervention or policy to move the systems in a particular direction or predicting the impact of an intervention or policy can be difficult (or perhaps even impossible) via reductionist approaches that attempt to isolate the effect of a given factor while keeping all others constant. This is because the effect of a given intervention on the system depends on the relationships and state of all other key system components. When used with scientific rigor, systems approaches may yield new insights into old problems, identify new important questions, and point to new kinds of data that need to be collected or processed in order to advance the goal of improving health in cities. Systems thinking also provides formalized ways for urban health researchers to link to other disciplines interested in the functioning of cities and allows input from various stakeholders and communities in the formulation of conceptual models and in the interpretation of results of simulation modeling. However, in order to be truly transformative these new approaches need to be employed to answer very specific questions and yield new insights. Moving beyond metaphorical discussions of urban systems to concrete applications that yield new information will be essential. At their best, the use of systems approaches will allow us to see and understand patterns and trends that researchers, communities, and policymakers may not otherwise be aware of. They may also allow us to identify the best ways to modify these patterns. Training in these approaches and the

development of exemplar applications will be important. Identification of specific types of situations in which systems approaches may be most useful will also be valuable. Systems approaches will never replace traditional quantitative and qualitative empirical approaches in urban health research, but if integrated with other strategies, they may help advance our understanding of the determinants of urban health as well as enhance our ability to intervene to improve health and reduce health inequalities in urban settings. Debate by Gerard Salem (following article): The word "approach" is original: is it a concept? A method? A tool? Beyond a naïve "natural interdisciplinary point of view", is it possible to adopt a systemic approach without hypothesis (and of course an explicit hypothesis: we know, as does Popper, that when a hypothesis is not explicit, it is implicit and irrefutable…). Debate by Sandro Galea (following article): There is little question that the field of urban health specifically, and public health more broadly, remains quite far from the widespread adoption of systems thinking. Our mainstream training, scholarship, and practice of urban health remains centered explicitly on causal paradigms that suggest we can effectively isolate causes that are instrumental in the production of health. This leads a quest for singular causes that can serve as levers we may manipulate to improve the health of these populations. Debate by Anthony Capon (following article): Systems approaches provide an effective way of understanding the dynamic interplay between the health of people, places, and planetary systems – a human ecological understanding4. Response by Ana V. Diez Roux (following article): Several commentators emphasize the value of systems thinking as a conceptual approach that extends well beyond the use of specific systems simulation tools. ... An important element of the use of systems approaches is the ability to incorporate and integrate various types of information (as noted by Carvalho) and also community and stakeholder input, enhancing co-production of knowledge (as alluded to by Capon & Siri and Dora). ... An important theme that arises in several of the commentaries is whether the advent of systems thinking and systems approaches will or should replace the other analytical tools we use to understand the drivers of health in cities or to evaluate the impact of policies and interventions. ... As noted by Galea, context dependency is certainly a hallmark of many of the phenomena we study and, indeed, a feature of the world itself!
05 - B. E. White
The author favors a simple definition of a CS: where the principal stakeholders are included in the system intentionally. As such, one realizes that nobody is in full control nor can be expected to predict what will happen as the CS evolves. Clearly, this is because people will do whatever they are motivated and rewarded to do. One can only influence what is often called a sociotechnical system, rather than control and manage it, by and trying to enlist support from others who sympathize, mitigate potentially adverse effects generated by antagonists. Solutions to CS problems are generally achieved from bottom-up and lateral, self-organized interchanges and activities, not by top-down dictatorial direction and hierarchical impositions.
06 - Barry Bozeman
A plurality of organizational forms, government alongside private, can help disperse power in society … What is at stake is not only efficiency but also democracy. Herbert Simon (1998, p. 10) Students of public policy and of organization studies rarely collaborate or even pay much attention to one another's work. There is no implication, for example, that the role of "public" is simply to address market failures. Publicness does not equate to government just as privateness does not equate to business. The theory has an inherent malleability, not a false one, but one rooted in its dimensional structure. This malleability has extended the domains to which dimensional publicness may be applied. Unfortunately, the recent history of graduate education seems to be more focused on domain contraction than expansion. This is especially the case in the USA (the walls in European universities seem a bit more permeable). graduate education provides hope for cross-fertilization. Students tend not to have "frozen" cognitive frames or ideological rigidity about specializations. Some business schools already provide considerable cross-sector education. There is perhaps a role for government funding institutions and private foundations. The history of collaboration and field change shows clearly the power of financial incentive. Another route to developing new fields or crossing old ones is to be reflexive in our collaboration efforts, taking academic knowledge of field change and putting it to practical use. This is a daunting task, using science studies to possibly affect the course of science, but is at least an interesting approach. Let us consider some possible lessons. We know, for example, that it is not necessary to build ever-increasing momentum in collaboration. Studies of the growth of new, emerging scientific fields (Bettencourt, Kaiser, Kaur, Castillo-Chavez & Wojick,

2008; Chen et al., 2009) and new patterns of collaboration (Graham, Lepenies, & Weingart, 1983; Leydesdorff, 2007; Newman, 2001) show that there are inflection points which, after they are attained, give rise to "contagion effects" sufficient to sustain the continued growth on new scientific topics. interdisciplinary work, though it develops more slowly that most imagine, occurs most often in adjacent fields that have some common conceptual ground and common methods, which is arguably the case for public policy and organization studies. Finally, one possible approach to a social science that is less conscious of field barriers is to pursue research and theory aiming at breadth rather than currently trending highly specialized approaches that rely more on manifest technique than on deeper explanation.
07 - BD Jones, FR Baumgartner
Incrementalism is updating from the last period's policy decision. Incrementalism implies that policy choice at a particular time is a marginal adjustment from a previous policy choice. The model has been thoroughly discredited by theoretical, methodological, and empirical critiques, but it survives because no convincing alternative has been offered. All of this does a fine job of explaining where the drag comes from—why decision makers might rely on the status quo and adjust policy from that point. But it does not offer much of a guide concerning how decision makers arrive at these adjustments. If incrementalism holds, then the distribution of policy changes across time must be normally distributed. If it is not so distributed, incrementalism cannot be the right model for the decision process. It is critical to understand that a straightforward incremental policy process will invariably lead to an outcome change distribution that is normal. And vice versa: any normal distribution of policy outcome changes must have been generated by an incremental policy process. Punctuated equilibrium (Baumgartner and Jones 1993) predicts outcomes consistent with budgetary leptokurtosis, with long periods of policy stasis interrupted episodically with bursts of rapid policy change. But punctuated equilibrium is narrower than incrementalism; it is a policy-making model but not fundamentally a decision-making model. In important ways, incrementalism is both, because it predicts a path of policy outcomes (''product incrementalism'') and a decision-making style (''process incrementalism''). However, underlying punctuated equilibrium is a decision-making model, attention-driven choice (Jones 2001; Jones and Baumgartner 2005). So in politics a good starting point is to ask how policy makers attend to and prioritize information.2 We actually have good theories about what to do if we have lots of noisy information about the state of the world. In fact, the standard incremental model has a ''hidden assumption'' in it: that decision makers update in a fashion consistent with the implicit indicator approach. That is, the incremental model will yield a normal distribution of outcomes only if policy changes are keyed to a sum of external events.3 If incremental decision makers do not update according to an approximation of the implicit indicator approach as laid out here, the distribution of their decisions will not be normal. The fact that U.S. budget authority is definitely not normally distributed tells us something very important. It must mean that adjustments in budgets (that is, changes in budget allocations) are not simple sums of external challenges. That is, policy makers do not just study the various sources of information that they have available to them, combine them in some sort of index, and produce policy keyed to the index. Nor do they incrementally adjust from the last period's change with the adjustment keyed to numerous additive causes, consciously (via index construction) or nonconsciously (because whatever causes updating somehow mimics index construction). If they did that, budget outcomes would be normally distributed. Bounded rationality and attention-driven choice imply that people are unlikely to follow an index-construction strategy in dealing with most of the choices they face. Rather, they are more likely to hone in on one aspect of a complex situation and key decisions to that aspect. Leptokurtic distributions in policy choice are prime indicators of disproportionality in the choice process. An institution may be defined as a set of individuals acting according to common rules resulting in collective outcomes. Attention allocation and the general bias toward the status quo in most systems of decision making work to delay responses; but then internal dynamics can operate to respond increasingly intensely to the stimulus via positive feedback effects. But based on our understanding of the structures of American government, we are pretty sure that the institutional costs of the Madisonian variety operate to cause delays in responses. These institutional facets can be overcome, but they generally operate in a single direction: toward more delay.

No friction, no leptokurtosis. It is that simple. One irony in our study is that the early incrementalists may have erred partly by not realizing just how right they were. Their model of boundedly rational information updating clearly recognized that policy makers could not make systematically comprehensive adjustments to changing environmental signals. The model that we have proposed here and the empirical results from the U.S. federal budget presented in figure 1 show a tremendous tendency toward incrementalism. The size of the central peak in these distributions is enormous when compared to the normal distribution. This reflects the inability or unwillingness of decision makers to react proportionately to moderate changes in the environment; rather, they tend to underreact to these. What the incrementalists overlooked, and what we add in this approach, is the direct corollary of the disproportionate response that they incorporated in their early models: that information that is ignored will accumulate over time, producing occasional lurches or policy punctuations. These produce the ‘‘fat tails’’ characteristic of the leptokurtic distributions that we have shown empirically and derived through simulations. The incrementalists got it right but told only half the story.
08 - Brian W. Head, John Alford
Thus, problem definition tends to imply a preferred solution. Some caution is therefore required with any proposed methods or approaches for addressing wicked problems, as they are likely to be provisional and incomplete in various degrees. Recent writers have tended to emphasize that attempts to address wicked problems often lead to poor results or unforeseen outcomes. In short, the conventional structures and systems of the public sector are not scoped to address the tasks of conceptualizing, mapping, and responding to wicked problems.
09 - Charlan D. Kroelinger, Kristin M. Rankin, David A. Chambers, Ana V. Diez Roux, Karen Hughes, Violanda Grigorescu
N/A
10 - Christina Seidel
Public policy-making is listed by ISO as one of the potential direct applications of LCA (ISO 2006). ISO states that LCA can assist in decision-making in industry, governmental, or non-governmental organizations (ISO 2006), which would presume to include public policy development. Life cycle assessment (LCA) has been used by decision-makers across the European Union, Japan, Australia, and many other countries to inform public policy (CIELAP 2009). However, LCA has not been used within public policy development as much as it has been applied to other applications such as product design (Allen et al. 1995). This shows the difficulty in obtaining participation from non-profit organizations whose resources are already stretched. If funding is available, offering to offset participation costs for public non-profits may mitigate this barrier
11 - D Hunter, N Perkins
Despite the sizeable body of research that now exists on partnerships, most of it is confined to issues around process and structure rather than outcome. Being able to establish the link, if any, between partnership working and outcomes for service users is notoriously difficult to do with any confidence
12 - D Young, R Borland, K Coghill
Systems change their structures and processes (how they do what they do) within limits defined by their response repertoire. This repertoire becomes more limited as the system optimizes its capacity around responses that have previously been successful.6(p205–207) Consequently, the potential for structural or procedural change becomes constrained over time. In addition, systems are typically unable to change their functions (what they do) from within, especially when their activities take place within a context characterized by polarization and stalemate,7,8 such as the tobacco control domain.2,9 Fundamental, innovative change requires action outside existing system structures. External actors include internal people (or groups) acting outside their system roles and external people or groups who, while varying in the intensity of their relationship with the system, believe it is not delivering. Management increasingly recognizes advantages in incorporating the views and actions of external actors when analyzing problems or redesigning systems. 10–13 These actors are not structured into any system, but act as a functionally coordinated network with respect to a potential change.14–16 Policy innovation involves at least 4 stages to create a reformed system: establishing the issue or problem (autonomization in ANT terms), developing possible solutions, contesting possible solutions, and institutionalizing, implementing, and refining the preferred solution. Most extant theories

of change or innovation focus solely on 1, or at most 2, of these stages. For example, systems thinking17–20 focuses on problem identification (but not how it becomes autonomized), and on potential solutions, whereas (social) diffusion theories,21,22 knowledge management theories,23,24 and approaches derived from complexity theory25 focus on the last 2 stages.26

Actor networks are heterogeneous.4 Unlike social networks16,22 associated with diffusion theory, they are networks of people, research evidence, technologies, financial resources, institutions, and regulation acting together to produce the innovation. The development of an actor network necessarily signals the pursuit of a goal (e.g., banning smoking in indoor public spaces), which generally stimulates the development of counter networks, or ‘‘anti programs,’’ 32,33 with different goals (e.g., dedicated smoking rooms with hi-tech ventilation) or that seek to block the goal being sought. They compete for allies, institutional endorsement, public support, and tangible and intangible resources.

Governments, aware of the evidence and public opinion, saw little reason for inaction and moved toward implementation.

Decisionmakers, especially in government, are more likely to autonomize problems, and institutionalize solutions, when they can see a critical mass of stakeholders being engaged by a specific solution and when alternatives are marginalized.

Problems like tobacco control and managing climate change share the need to engage external actors in problem formulation and solution development. No single subsystem, whether government or any other, can solve these problems from within. In both cases, there are stakeholders with sufficient power to stalemate solutions that can be framed as threatening their interests. Governments will increasingly be faced with situations in which the achievement of public goals depends on their ability to constructively engage with external actors. Governments can produce engagement in 3 ways: mandatory requirements, financial or other incentives, or collaboration. In situations in which it is easy to achieve stalemate because of complex interdependencies between finely balanced, powerful coalitions of interest, inducing or forcing actors to engage will not suffice. A collaborative, deliberative approach,10–12 especially where the mobilization of science is critical to decisionmaking, 13 produces better outcomes.

13 - Douglas A. Luke, Katherine A. Stamatakis

As Meehl (102) has pointed out, rejecting a null hypothesis of no effect is a very low epistemological bar, and the social and health sciences are better served by proposing richer predictions based on more sophisticated models of causal mechanisms. Thus, if we are to study complex public health systems, we need to use study designs and methods that allow for interactions among elements of the complex system and that are able to study, identify, and characterize the mechanisms that drive the behavior of the system (54).

Stated most concisely, the types of statistical analyses that we use most often in public health are inappropriate for studying complex systems. Even more sophisticated analytic techniques, such as structural equation modeling and latent class analysis, which are designed to test more complicated relationships, break down in the presence of all-too-common feedback loops, threshold effects, and other types of nonlinearity. Critiques of statistical modeling are not new, but a common theme of these discussions is that statistical models are most useful when they are connected to strong study designs and appropriate data and match the structure of the theoretical predictions (52, 91).

Complex system methods challenge traditional study-design and data-analysis approaches in public health research.

The field of complex system methods appears to be moving toward greater integration among the systems science methods to account for the interaction between social networks, broad system boundaries, and individual behavior to improve the utility of models for policy and practice decision-making that span multiple levels of influence (113).

Despite the promise of systems science methods for public health, these models remain underutilized and lack visibility (137, 140). Although a number of institutions and settings around the country do train and support system scientists (e.g., University of Michigan’s Center for the Study of Complex Systems, the Santa Fe Institute, NIH’s Institute on Systems Science and Health), schools of public health are only now starting to think about developing their own curriculum and degree programs. Although a brief review of course offerings in the top 20 schools of public health in the United States found that about half offered at least one course that addressed a complex system method, it is not clear that such coursework is well integrated into the methods curricula. Moss (110, p. 1) suggests that computational modeling and system science is a “third way” that moves beyond traditional quantitative and qualitative research design dichotomies. If this is so, then we need to start producing

more public health scientists who are comfortable and skilled using concepts and tools that focus on dynamics, agents, and networks and ensure that the public is aware of the benefits of this approach to public health science.
14 - Edward H. Ip, Hazhir Rahmandad, David A. Shoham, Ross Hammond, Terry T. -K. Huang, Youfa Wang, Patricia L. Mabry
N/A
15 - Emily F. Gates
Unexamined and inappropriate assumptions can lead to intervention failure, policy resistance, and negative unintended consequences for an intervention
16 - Eric Silverman
In population health, these are called wicked problems, where causal links between risk factors and outcomes are not well defined, and unearthing the mechanisms that drive these processes is difficult [6]. As efforts to address these wicked challenges with traditional methods have floundered and failed to produce effective and actionable policies, population health scientists have increasingly turned toward the conceptual frameworks of complex systems science and simulation methods to find a way forward. As an example, take the ODD protocol for documenting agent-based models, first conceived in 2006 in ecological modeling circles, then later expanded to ODD+D for social models and recently ODD+2D for data-rich social simulations; as the method spread, new norms and techniques developed that have helped ABM become a more trusted tool across numerous disciplines [2]. On the whole, the field seems to be on the cusp of a significant shift toward systems-based approaches, and as these efforts expand and funders begin taking note, this is an ideal time for the ALife community to get involved
17 - Gemma Carey, Eleanor Malbon, Nicole Carey, Andrew Joyce, Brad Crammond, Alan Carey
A general distinction is made between 'hard' systems methodologies which refer to quantitative dynamic model building (ie, system dynamics) and 'soft' systems methodologies which refer to qualitative, action-based research methodologies (ie, critical systems heuristics). Research on the implementation of systems-type interventions has shown that without training and clear guidelines on systems-based implementation, then practitioners resort to their previous experience in delivering multicomponent reductionist-style interventions.45 Arguably, this is the systemic issue that is slowing, or muddling, public health's attempts to engage with systems-based approaches. Thus, while some interesting methodologies are beginning to develop in this area, at this stage it appears that researchers are primarily assessing when and where systems practice and evaluation are occurring rather than appraising the utility of systems practice and evaluation itself. These researchers conclude that more practical guidelines, training and partnership with experienced systems modellers are required if we are to see systems concepts applied more broadly in public health practice and evaluation. Lich et al1 contend that despite a growing appreciation for 'multiple levels' and systems of influence, public health is yet to take full advantage of the analytical approaches—or toolbox—provided by systems science.
18 - Guruprasad Madhavan, Charles E. Phelps, William B. Rouse, Rino Rappuoli
The core issues in population health planning, often behavioral, financial, and involving joint operations, are exacerbated by barriers, some hierarchical (city, county, state, federal, international) and some jurisdictional (i.e., cross-organizational). Everybody has some responsibility for population health, but nobody is in charge. A relevant illustration pertains to recent efforts regarding opioid abuse and deaths. One response was to control the amount and duration of opioid prescriptions, which in return led to increased overdoses and deaths from addicts switching to street drugs of highly variable potency and quality. Clearly, the "system" of substance abuse extends well beyond prescription-based medical care. The prohibition of prescriptions removes the blame from the medical system but does not resolve the epidemic. The plethora of plans, planners, and planning activities for various diseases are representative of the complexity. Examples exist in which strategic plans for control of challenges such as obesity, diabetes, cancers, and neurodegenerative conditions have diffuse roles in many organizations but with no central responsibility or even any mention of budget authority to accomplish the stated task. We believe that a well-integrated systems approach to understanding the actual drivers of these behaviors and actions and their cumulative effects on population health is essential for improvements in resource planning and allocation in support of desired health outcomes. The primary value of a systems architecture is to illuminate the basic relationships and influences and a pathway for practical integration among the entities and the participants. The component models provide a quantitative and

qualitative profile of the systems architecture.
The systems architecture for population health could feasibly materialize through the alliance of current capacities in systems engineering, computing, network and complexity science, information processing and storage, interactive gaming, and predictive analytics (now indeed common in utilities, finance, sports, weather, entertainment, and politics). As a next-generation challenge, we propose that the modeling and visualization communities could develop a situational-awareness platform that could provide live operational snapshots of programs, real-time functional portraits, and dynamic flows and foreseeable trends in matters of population health.
Projection of the value of investments in population health would require both "income statements" and "balance sheets" to trade off near-term expenditures and long-term returns (8). Determining the value of investments by focusing only on the individuals in the population health system is insufficient and needs to extend to the governance and leadership of corporations that provide the many types of services (medical care, education, food supply, vehicle safety, and many others) that affect health and well-being.
The practical notion of incentives and behavior modification expands to interorganizational (and international) arrangements.
Ultimately, enterprise-level transformation of population health, as envisioned here, typically embodies fundamental shifts that challenge the current mode of operations (22)
Universities and research institutes have important roles to play at all levels of the systems architecture for population health. However, the competencies needed to address these issues are often currently taught and researched in relative isolation, without a sense of the need for integration across subjects, departments, and schools. Academia's penchant for increasing hyperspecialization is obstructive and counterproductive to the multidisciplinary systems perspectives needed to advance population health. As the late systems theorist Russell Ackoff once stated, "We must stop acting as though nature were organized into disciplines in the same way that universities are" (ref. 27, p. 6).
New approaches for conducting research are needed for population health, especially when discovery science is still dominantly viewed as the mechanism to gain tenure and fame.
A central element of a systems architecture involves shifting from fault finding to fully streamlining and fixing the system (32). In other words, just "staying in one's swim lane" protects organizations and their vested interests but is inadequate for addressing the needs of population health. A systems architecture can highlight or stimulate new competencies at the junction of health, engineering, nursing, behavioral sciences, industrial design, business, policy, sociology, anthropology, civic studies and organization, rural and urban planning, public works maintenance, marketing, computing, game design, communication, and cultural evolution. Understanding and improving population health is a systems problem and not a narrow concern of surgery, nursing, precision medicine, or other healing arts, let alone genetics, bioethics, and insurance. This broader frame potentially motivates a substantial review and revision of our current funding and investment priorities, how we conduct research, and for what purpose.

19 - I. David Wheat

Hill (1993, p. 235) articulated the new view that policy ends are often reshaped by administrative means: 'What [the Wilsonian view] was prone to disregard was the extent to which [public administration] would tend to transform policy, often fundamentally. Implementation must be seen as part of policy-making'. And Bardach (2005, p. 33) supports the normative implications of the new perspective: 'Even the best policy planners do not get all the details right in the design stage. They should therefore allow room for policy implementers to improve on the original design'.
More often than not, public policy analysis is limited to the study of parameter changes in a model. And that is problematic because improvements in systemic behaviour require improvements in systemic structure. Designing policy structure for public sector models is not easy. It requires a capacity for operational thinking in what may be unfamiliar political and bureaucratic contexts.

20 - Jacqueline Merrill, Michael Caldwell, Maxine L. Rockoff, Kristine Gebbie, Kathleen M. Carley, Suzanne Bakken

Salinsky & Gursky: natl. need to augment PH mgr. ability to build adaptive organizations
Organizational theorists observe that organizations typically consist of dense, minimally overlapping subgroups that integrate with the larger organization through contacts outside the boundaries of the group.
Theories of collective action in network research suggest that centralized networks are more likely to be successful in achieving common good functions. Centralized organizations use a top-down model of decision making vs. decentralizing authority closer to the point of service. This is effective when the central core uses its

tight connections to manage resources and integrate tasks, but centralized structures can risk overburdening those at the center with too much information while underutilizing the abilities of peripheral members. Programs with mobile field staff might perform best with a highly centralized structure, but too much centralization can prevent a unit from exercising discrete task resolution and forming interunit ties.
21 - Jessica G. Burke, Kristen Hassmiller Lich, Jennifer Watling Neal, Helen I. Meissner, Michael Yonas, Patricia L. Mabry
N/A
22 - JM Bauer, PM Herder
Although an analytically precise definition is difficult to formulate, for the purposes of this chapter socio-technical systems will be operationalized as arrangements of multiple purposive actors and material artifacts interacting in ways that require analyzing the total system and not just the constituent subsystems (see [Ropohl, 1999] for a more detailed discussion). Depending on the level of analysis and the research questions asked, each subsystem can be further disintegrated to dissect its logic and internal dynamics. Each subsystem aims to meet its own objectives, by using its own means, but is also in an interdependent relation with other subsystems. Important design decisions at the technical and social level are, consequently, often made without a clear view of the overall implications of these decisions for the development of the socio-technical system as a whole. Comprehensive system thinking dates back to writers in the eighteenth century, who compared societies to organisms (e.g., [La Mettrie, 1748/1912]). Cybernetics [Wiener, 1948] inspired Parsons' [1951] structural functionalism. Further attempts at a systematic theory were made with general systems theory [Bertalanffy, 1968] and mathematical systems theory [Mesarovic and Takahara, 1975]. In Germany, Luhmann [1995] and his collaborators developed a unique version of systems theory with a strong emphasis on communication processes within and between subsystems. All these approaches have in common that the reproduction of the system imposes certain functional requirements. Effective design is only possible in as far as it is compatible with system logic and functional requirements [Schneider and Bauer, 2007]. Systems models attempt to understand the dynamic processes generated by the interaction of component subsystems, which in turn may consist of interacting subsystems. In that sense they are a good match to the problem structure of multi-layer systems found in socio-technical systems. Whereas system theory is not predominantly a theory of design, its insights can inform the actions shaping socio-technical systems, at least at a conceptual level. Moreover, even if a decentralized system works in principle, forms of market deficiency may require interventions to assure certain public values, such as universality of access to infrastructure services. An important consequence of the system's heterogeneity is that higher system levels often display unpredictable behavior. Decision making and designing in the SoS paradigm requires an approach that cuts across various domains, combining, for instance, economic decisions with engineering design and policy making without losing the strengths of either modeling domain As designs and interventions are rarely based on a full understanding of all the relevant interactions and dynamic effects, specific choices often also have unanticipated effects. Only in rare circumstances ("leverage points") will it be possible to design and implement effective comprehensive designs although even in these cases the full implications of choices may only be realized in hindsight. One of these leverage points is the overhaul of the legal and regulatory framework of a sector ("constitutive moments", see [Starr, 2004]). Like system theory, it highlights the importance of the overall rules, within which a sector evolves, on its performance, without claiming that there is one preferred set of rules (e.g., an "unregulated" market). Complexity is a matter of degree. If an industry is in static equilibrium or in a steady state expansion path, insights gained from complexity theory would converge with the results of constrained optimization models. However, if these conditions do not hold — and recently deregulated infrastructure industries are most likely not in such an equilibrium state — it points to aspects that are often overlooked by other approaches. The emphasis on unpredictability challenges traditional notions of design. In extreme cases, purposive design will not be possible. The theory of complex adaptive systems does, however, yield insights that can be used for the design of systems even in these situations. Third, the theory of complex adaptive systems identifies several processes to improve performance ("fitness" in the terminology of [Kauffman, 1983; 1995]). An "adaptive walk" strategy varies single features of the design and observes its effects on system performance. Only changes in design that improve performance are retained. Such strategies will gradually approximate a local optimum but may be insufficient to reach an alternative, possibly superior optimum if it would require incurring temporary efficiency losses. For example, realizing a more efficient overall energy supply system may require short-term inefficiencies during the reorganization of the system. In such cases, "patching", the assignment of tasks to distributed units combined with some overarching

coordination mechanism, might be a feasible strategy. For example, federalism can be considered a form of a patching mechanism: individual states may serve as laboratories for new policies from which a federal government can then pick successful approaches that are applied to the whole system [Cherry, 2008]. Such an approach may have desirable properties and enable the system to reach higher than just local optima. Only if the overall design problem can be segmented in a way such that every incremental local improvement will also contribute to improvements in the global performance of the system will the constrained optimization approach yield reliable outcomes. In general, the new reality of socio-technical infrastructure design is better reflected in multi-stakeholder system models and complexity theory. In practice it is also reflected in a shift from outcome-oriented forms of design to process-oriented forms of designing both institutional and technical system aspects. Much of the regulatory reform debate, which is predominantly directed to redesigning the social framework of infrastructure industries, is based on economic concepts. Important goals stated by economists for the design of the institutional and sectoral arrangements are technical efficiency, productive efficiency, allocative efficiency, dynamic efficiency (innovation), adaptability/resilience, stability/security, universality of access to services, and sustainability. Some of these goals overlap with engineering objectives. Productive efficiency refers to producing any given output with the least-cost combination of inputs. Allocative efficiency requires, intuitively stated, that the mix of goods and services produced matches their valuation by consumers. Dynamic efficiency refers to the innovation rate in a system and the associated inter-temporal resource allocation decisions. Under other conditions, for example, the prevalence of externalities, public good characteristics, the existence of natural monopoly characteristics, this result does not hold and social intervention may move the system closer to the optimum. Moreover, even if a decentralized system works in principle, forms of market deficiency may require interventions to assure certain public values, such as universality of access to infrastructure services. Infrastructure industries have, therefore, evolved from a controllable monopoly system to a less controllable adaptive dynamic system [Bauer, 2004]. The explicit or implicit assumption of policy-makers was that the anticipated higher efficiencies of the more dynamic system outweigh its possible costs. Such costs include the heightened coordination requirements, the possible dynamic frictions and inconsistencies, greater difficulties of safeguarding public values, as well as the reduced ability to influence the overall evolution of the infrastructure system.
23 - Julie M. Kapp, Eduardo J. Simoes, Anne DeBiasi, Steven J. Kravet
Through its provisions and strategies, the ACA has generated attention for programs that drive a systems engineering approach to healthcare services (Cassel and Saunders, 2014; Executive Office of the President: President’s Council of Advisors on Science and Technology’s, 2014). Indeed, a call for re-engineering the US healthcare system by using complex adaptive systems theories is not new (Institute of Medicine and Committee on Quality of Health Care, 2001). Given that many of the strongest predictors of health and well-being fall outside of the traditional healthcare setting (National Prevention Council, 2011), applying a systems thinking approach to population health would be a high-impact strategy towards reducing the health disadvantage. No studies have yet applied a systems thinking framework to US population health. We recognize that the application of the Baldrige Framework to US population health is an idealized design. As an idealized design, it is believed to be unattainable but towards which progress is believed to be possible, and is ideal-seeking in its purpose while also being (i) technologically feasible; (ii) operationally viable; and (iii) capable of rapid learning and adaptation (Ackoff, 1977, 1981, 1999). 'There must be incentives in place for managers and staff to use results-based management’.
24 - Juliet Sims, Manal J. Aboelata
The nation’s health problems are so pervasive, the solutions are so complex and costly, and the resources for addressing them are so fragmented that no single sector can achieve large-scale, sustainable results on its own. —Alonzo Plough (2015, p. S151) We believe that a systems approach—one that addresses the interrelationships of multiple factors—may create some of the biggest opportunities to achieve health, safety, and well-being, and reduce health inequities—because systems that are currently producing poor health outcomes and health inequities can be redesigned to produce health, safety, and equity. As Smedley and Syme (2001) wrote in the National Academies of Science Engineering, and Medicine report Promoting Health Intervention Strategies From Social and Behavioral Research, “It is unreasonable to expect that people will change their behavior easily when so many forces in the social, cultural, and political environment conspire against such change” (p. 5). To redesign systems so that they achieve health, safety, and equity, we need

to act at multiple levels. These include (1) strengthening individual knowledge and skills, (2) promoting community education, (3) educating providers, (4) fostering coalitions and networks, (5) changing organizational practices, and (6) influencing policy and legislation.
25 - Kristen Hassmiller Lich, Jennifer Brown Urban, Leah Frerichs, Gaurav Dave
Recently there have been increasing calls for research, practice, programs, and policies to be grounded in systems thinking within the fields of evaluation (Patton, 2011; Williams & Imam, 2006) prevention science (Hassmiller Lich, Ginexi, Osgood, & Mabry, 2013), public health (Leischow et al., 2008; Luke & Stamatakis, 2012; Mabry, Marcus, Clark, Leischow, & Mendez, 2010; Mabry, Olster, Morgan, & Abrams, 2008), dissemination and implementation (Best et al., 2003; Burke et al., 2015; Hassmiller Lich, Frerichs, Fishbein, Bobashev, & Pentz, 2016; Powell et al., 2015), urban planning (Tozan & Ompad, 2015), and global health (Adam & de Savigny, 2012). Thinking in causal linkages and feedback loops is a new way of understanding reality for people used to thinking of systems in terms of their components and linear relationships between parts (e.g., logic models or flow charts). While SD offers an approach to “connecting the dots” between GCM constructs, several other cautions are important for teams preparing to use the method.
26 - M Schwaninger, S Ulli-Beer…
N/A
27 - Marta Lenartowicz
Hence, while the early systems thinking offered a mental model to conceive of a specific mode of exercising public governance, this model did not furnish the conceptual tools to design and assess the efficacy of policies inspired by its general principles. On the grounds of public policy and governance, this very dilemma seems to have been resolved quite radically by removing the boundaries of the target organizations altogether and construing much larger objects of public interventions instead: the economy, its specific sectors, the functional system of specific public goods provision, society, culture, and so forth. Even though it is somehow presumed that a change in the functioning of, for example, a public health system depends on a variety of implemented organizational changes in a large number of organizations, a thorough review in terms of organizational change and organizational management is hardly pronounced when conceptualizing of strategic public policy. What public policy is interested in and how it is willing to measure and evidence its effectiveness are more general indicators which can be assessed without any conceptual penetration of the organizational black boxes. Autopoiesis is the repeating, circular creation of oneself anew, realized through the re-production of one’s own components through the work of other components of oneself. This process is the basic reason for the work of each of the components, so that the main reference point and goal of the work of the whole living system ultimately turns out to be itself. Such self-directedness of all internal processes differentiates autopoietic systems from other, allopoietic systems (Maturana & Varela 2010: 135) which are constructed by an entity other than themselves and which carry out specific functions in relation to that entity. When the perturbation (i.e., the stream of grants) expires, so will the compensation, and the targeted organizational systems will simply return to their previous ways. The conceptual lens of the theory of autopoiesis makes it clear that if the collaboration with industry and business is to become a permanent feature of the way the universities work, the goal for public policy must be their self-transformation—a shift in the underlying pattern. the most optimistic, possible scenario can only be this: parallel to the process of externally inducing change, a self-transformation of the organization happens to take place, the direction of which coincides with the intentions of the policy-makers
28 - Mary E. Northridge, Sara S. Metcalf
Attempts to model the system rather than the problem are bound to lead to confusion and futility
29 - Navid Ghaffarzadegan, John Lyneis, George P. Richardson
While larger or more disaggregated models are appropriate in some circumstances (see Sterman, 2000, Ch. 6, for a discussion of the appropriate model boundary and level of aggregation in system dynamics models), for many public policy problems a small model is sufficient to explain problem behavior and build intuition regarding appropriate policy responses. Swamping Insight Model: In contrast to what policymakers intuitively expect, a rise in the upstream capacity makes outcomes worse by increasing the number of families on TANF as well as the total number of families at risk (Figure 6(a)). The reason for such counterintuitive results is as follows. By increasing the upstream capacity, more people flow to the downstream and the load on the downstream increases. If we assume limited capacity in

the downstream, people may not receive quality downstream services, causing their condition (e.g., their economic condition) to deteriorate. Ultimately, such families return to the TANF program, reloading families on TANF. In contrast, an increase in the downstream capacity (Post TANF employment support capacity) has a positive effect on the system by decreasing the number of families on TANF and the total number of families at risk (Figure 6(b)). Such a policy decreases the load on downstream as well as decreasing the load on upstream by decreasing recidivism. Naturally, policymakers are prone to concentrate on the part of the system for which they are most responsible. After focusing more and more people at the upstream and in the absence of a holistic view of the system, policymakers may attribute worsening outcomes to exogenous infl uences. In reality, it is their own policy that has reduced downstream services and raised the level of recidivism. In many cases, small models may emerge only after extensive examination of a larger model allows for the identifi cation and isolation of only the most dominant feedback loops. Once a large model is developed and the modeler gets a clear idea of the dominant loops, he or she can build a smaller version to present for policymakers.
30 - Nicholas P. Patorniti, Nicholas J. Stevens, Paul M. Salmon
Systems approaches have the potential to provide an unprecedented means for all stakeholder groups and city authorities to better understand the complex social, economic and political interconnections inherent in urban systems To date, systems approaches have suffered due to the scale and vast complexity of the problem. Human factors and ergonomics, specifically, STS approaches, have a theoretical, methodological and practical legacy of understanding and designing complex systems.
31 - Philip Haynes
one of the epistemological problems, however, with taking scientific methods and exporting them into the applied world of social science, is the resulting value base (or apparent lack of an explicit value base). Molina (2015: 49-50) explores the value conflicts that public managers experience in practice and proposes that one key definition in the fault line of these conflicts is when 'values of bureaucracy' conflict with 'values of democracy'. Molina associates 'values of democracy' with individual rights, citizenship and participation and the 'values of bureaucracy' with the requirement for efficiency and effectiveness. These conflicts translate into numerous policy examples and management decisions. For example, a public medical committee examining the efficiency and effectiveness of a drug decides that the cost benefit is not proven for a given population size. But in contrast an individual argues to their professional practitioner, who agrees, that such a prescription is warranted on the basis of their unique individual circumstances and their lack of realistic and available options with other treatments.
32 - Robin C. Purshouse, Alan Brennan, John Holmes, Petra S. Meier
Holder was an early advocate of systems approaches, identifying communities as dynamic and complex environments within which prevention initiatives play out their effects. By 'complex', Holder meant that there were numerous inter-related social factors that could influence the effectiveness of interventions [4]. In SimCom, Holder organized these into six interacting subsystems: consumption; retail sales; formal regulation and control; social norms; legal sanctions; and social, economic and health consequences [3]. The factors, and relationships between them, were formalized as a set of coupled differential equations1 and were implemented in a computer model. Most notably, in addition to producing estimates of intervention impact, this model proved able to reproduce historical community-level trends in alcohol consumption [5], a key indication that a model may be valid. Apostolopoulos et al. rightly draw attention to a range of methodological challenges associated with complex systems approaches. In particular, defining analytical boundaries and levels of abstraction for the system can be challenging. Recent advocates of complex systems models within public health also point to difficulties in parameterizing models with currently available data and to entrenched disciplinary thinking which focuses upon simple associative relationships found within available data sets, rather than synthesizing multiple data sources to simulate wider processes [9].
33 - WM Trochim, DA Cabrera, B Milstein, RS Gallagher, SJ Leischow
Modern public health practice encompasses a complex, loosely coupled system1 of actors including governmental entities at the international, national, regional, and local levels; a diverse conglomeration of nongovernmental organizations (such as foundations, advocacy and special interest groups, coalitions and partnerships, for-profit and nonprofit medical systems, and businesses); and citizens in the public at large. The broad array of threats to well-being, ranging from obesity and tobacco use to violence and infectious diseases, can be most aptly portrayed from a complex and adaptive system perspective.

The authors of an Institute of Medicine report, Crossing the Quality Chasm: A New Health System for the 21st Century,11(pp8–9) used a systems perspective to delineate 10 “simple rules to guide the redesign of the health care system” and described the entire health care system as a complex adaptive system: "A health care system can be defined as a set of connected or interdependent parts or agents—including caregivers and patients—bound by a common purpose and acting on their knowledge. Health care is complex because of the great number of interconnections within and among small care systems."11(p64) Systems thinking is a general conceptual orientation concerned with the interrelationships between parts and their relationships to a functioning whole, often understood within the context of an even greater whole. Systems modeling is a methodological tradition that involves the use of formal models or simulations as explicit aids to increase our understanding of complex systems and improve the effectiveness of our actions within them. Computational modeling and simulation, as a complement to experimentation and theory, are hallmarks of recent systems thinking and the systems sciences.47 Consider just a few of the topics associated with contemporary systems thinking: causal feedback48; stock–flow structures and open and closed systems49; centralized, decentralized, heterarchical, hierarchical, and self-organizing systems50,51; autopoiesis52–54; nonlinear systems and chaos55; complex adaptive systems56–59; boundary conditions, scaling, power laws, phase transitions, universality, and renormalization55,60; silo effects61; emergence62,63; cellular automata64; fractal self-similarity46; general systems theory65; cybernetics66,67; control theory68; information theory69; computational simulation47,70; decision and game theory71; system dynamics72–77; evolution, biology, and ecology78–81; small world phenomena82–84; and set, graph, and network theory.53,79,80,82,83,85,86 Although the vast array of participating governmental, medical, public health, and nonprofit organizations involved in the EMS system have coordinated their efforts in various ways for several decades,92 it is not a centrally and hierarchically controlled system. Tens of thousands of people are trained in various roles by a wide variety of entities ranging from medical and public health schools to nonprofit organizations such as the Red Cross.93 Although individual agents may be aware of the existence of the broader system, their training concentrates on their specific part in it and how it connects with adjacent parts—the role they play and the rules they follow—leading to a system that can adapt to a great variety of individual medical emergencies. The ISIS team concluded that systems thinking in public health cannot be encompassed by a single discipline or even a single approach to “systems thinking” (e.g., system dynamics); instead, it consists of a transdisciplinary integration of public health approaches that strive to understand and reconcile linear and nonlinear, qualitative and quantitative, and reductionist and holist thinking and methods into a federation of approaches to systems thinking and modeling.103
34 - Y Bar-Yam
"The analysis presented here suggests that a public health system that promotes private organizations or publicly supported organizations (or both) that are effective at large-scale prevention and population care will be more effective in the long term." "the benefit of a multiscale understanding of the health care system is the recognition that changes in organization can be of widespread benefit, and this understanding should promote the adoption of change. Specifically, a wide range of players should recognize that changes that promote adoption of a prevention- and population-based care system will serve their goals and interests."

Table 19. Data Extraction from Articles

01 - A Vining
Methods: N/A
Results: N/A
Public agency strategic analysis (PASA) is different from public policy analysis because public agency executives face numerous constraints that those performing “unconstrained” policy analysis do not. It is also different from private sector strategic analysis. But because of similar constraints and realities, some generic and private sector strategic analysis techniques can be useful to those carrying out PASA, if appropriately modified. Analysis of the external agency environment (external forces) and internal value creation processes (“value chains”, “modular assembly” processes or “multi-sided intermediation platforms”) are the most important components of PASA. Also, agency executives must

focus on feasible alternatives. In sum, PASA must be practical. But public executives need to take seriously public value, and specifically social efficiency, when engaging in PASA. Unless they do so, their strategic analyses will not have normative legitimacy because enhancing public value is not the same as in some versions of public value or in agency "profit maximization". Although similarly constrained, normatively appropriate public agency strategic analysis is not "giving clients what they want" or "making the public sector business case". PASA must be both practical and principled.

When explicit analysis is undertaken, it may be primarily backward looking and evaluative: whether in the form of a "report card" [8], a multi-goal evaluation [9] (pp. 340–382) or a "balanced scorecard" [10,11].

Strategic analysis may be initiated because some relevant political or executive authority believes that the agency should fundamentally re-evaluate the relevance and validity of the goals or strategies that underlie and justify the existence of the program, unit or agency.

How should public agencies actually go about doing such strategic analysis? There are a number of potential meta-strategies. One response is to muddle along, or more formally, to rely primarily on "incrementalism", whether conceived as either logical or disjointed [19,20]. Another meta-strategy response is to focus on using and learning from simple strategy heuristics, especially in the presence of unpredictable and changing environments [21,22]. For public agencies, these heuristics would primarily result in considering mimetic strategies [23,24]. Another meta-strategy is to engage in an explicit exercise based on "relevant" theory, heuristics, experience and mimetic learning: the focus here.

Consequently, their analyses vary importantly in the breadth of their goals and the comprehensiveness of their analyses [25]. Partly because of the difference in constraints, public agency strategic analysis is different from all standard versions of policy analysis.

In a "worst case" analysis, policies based on an inappropriate version of public value could reduce social efficiency. I argue that unless social efficiency is a significant component of the meaning of public value, public agency strategic analysis cannot be normatively justified.

Difference between PASA and policy analysis: The first difference is that PASA often has a narrower jurisdictional standing focus and is necessarily interested in, and constrained by, the costs and benefits of the specific jurisdiction and its residents. In many cases its "standing" perspective is more limited than that used, and usually judged to be appropriate, for policy analysis or cost-benefit analysis (CBA) purposes [32,33]. ... Second, many PASAs encompass social values beyond efficiency, especially equity. ... Third, for strategic purposes, a PASA should include both an analysis of the agency/program's economic and political environment (external analysis) and an assessment of its own assets and social value creation process (internal analysis) [39]. ... A fourth difference is that a PASA focuses on the specific feasible agency alternatives.

Difference between PASA and firm strategic analysis: Goal difference; public agencies can only use some of the same components and tools

Four distinct meanings of public value: (1) the achievement of political mandates; (2) the achievement of professional standards; (3) the application of analytic techniques, such as revenue-cost analysis, cost-effectiveness analysis, or cost-benefit analysis (essentially the social efficiency perspective, although the focus is on the technique rather than the maximization of social efficiency), and (4) stakeholder and customer satisfaction

Values problematic because: First, many of these dimensions are at different levels of analysis and not directly comparable to each other in any meaningful way (for example, "budget keeping" and "professionalism"). Second, several do not appear to have normative grounding from a substantive policy perspective, if one did manage to combine them in some multi-goal analysis or "optimizing" perspective.

The distinctions between technical efficiency, allocative efficiency and dynamic efficiency are important and the practical proxies that can be used for each in either PASA or policy analysis vary. Additionally, to be useful for PASA purposes, one must demonstrate that social efficiency is a practical criterion that public agency executives can measure and use to operationalize the pursuit of public value [29,77].

Whatever the specific language, an assessment of social efficiency requires the agency to perform or access some form of analysis that assesses both costs and benefits that accrue to all those with standing, using some reasonable time frame for the program's impact: that is, it should be based on the net present value (NPV), rather than just the current period.

The public agency five forces are (in the order discussed below): supplier bargaining power, threat of

substitutes/entry barriers, user/purchaser bargaining power, extent of rivalry (actual competition or the threat of contestability) and political influence barriers.
The competitive forces framework diagrammatically shows all forces as flowing from external forces to (implicitly) the public organization being analyzed.
Supplier Bargaining Power: Because of the higher ratio of non-monetized inputs, the concepts of bargaining power (and "political influence barriers" as discussed below) in the public agency context are more multidimensional and complex than in most equivalent private sector markets [101,102]. Specifically, in the absence of monetization, bargaining power has "political" as well as economic dimensions. Given these realities, agencies have to engage in better bargaining strategies to reduce the bargaining power of suppliers and cannot simply rely on more specialized purchasing agencies [103].
Threat of Substitutes/Entry Barriers: The threat of substitutes occurs when: "A substitute performs the same or a similar function . . . by a different function [90] (p. 84). Substitution is often the greater threat to public agencies because while governments and their regulatory agencies can anticipate conventional entry and forestall it by law or regulation, it is more difficult to anticipate and forestall radical technologically based threats. ... In some cases, even conventional entry is possible in the absence of comprehensive legal barriers to entry. These legal barriers may currently limit the entry of either for-profit firms, or non-profits. ... With the advent of new cost-lowering technology, the threat of entry becomes real. Entry, and even the threat of entry (a form of contestability), can seriously erode strategic autonomy and induce strategic reactions.
User/Purchaser Bargaining Power: In the competitive force model, the degree of customer (or buyer) bargaining power is crucial: "Powerful customers—the flip side of powerful suppliers—can capture more value by forcing down prices, demanding better quality or more service (thereby driving up costs), and generally playing industry participants off against one another, all at the expense of industry profitability" [90] (p. 83). ... Two factors drive the added complexity: the frequent division between users and purchasers (buyers) and, relatedly, the high degree of variability in public agency user pay regimes [111]. ... The actual bargaining power of non-purchasing users depends on both their motivation to interact with agency executives and on the nature and extent of their resources, cohesion, and organizational skills. ... In some cases, these purchasers are central budget control agencies. In other cases, purchasers are other government "line" agencies. Purchasers are inevitably in some form of exchange relationship with the agency (as, of course, are users), but the leverage points in these purchaser relationships can vary widely. Budgetary and fiscal control agencies are typically primarily concerned with controlling or reducing payments to the agency and are not directly interested in bargaining to influence missions or policies, unless it directly affects total purchase expenditures. ... Agencies and programs vary widely in the degree to which they try to get users to pay for services. ... Public agency full-cost (or more) pricing is variable: it is more common for state-owned enterprises (SOEs), corporatized entities [114,115] and special districts (in the U.S.). In addition, even where users do pay a significant percentage of service costs, they often do so through, or with the advice of, agents (as in the private sector). These purchasing agents typically have stronger bargaining power than individual purchasers because of greater concentration and less information asymmetry (including more knowledge of other government agencies or non-profits that could supply the equivalent service or provide a viable substitute.
Extent of Rivalry: In competitive forces analysis, the intensity of rivalry is usually the most important force and is represented as the "central" force. ... Strategically, the contestability of a given program monopoly can be as important as the current state of competition that it faces. In many cases, an agency's program monopoly status is foreseeably secure: it is not contestable. The basis of an agency monopoly, such as the collection and analysis of basic national demographic information, may be based on the existence of significant economies of scale. ... In the absence of watertight legal barrier to entry, many programs do not have effective monopolies that can be expected to endure over time. Many agencies, especially at the regional and local level, provide services that exhibit neither significant economies of scale nor collective good characteristics, that is, they deliver private goods that are both rivalrous in consumption and excludable. Structural cost factors alone do not foreclose competition that might enhance efficiency from not-for-profit or even for-profit competitors. Many local services are delivered by "mixed contracting" where a public agency competes to some extent against contracted service. ... One reason that many public agencies, especially corporatized ones, face increased competition is that they are increasingly being required to charge prices for their services

that meet or exceed the cost of provision [114]. If agency prices are forced to approximate the marginal costs of delivery, then an agency become subject to competition or the threat of entry by private-sector competitors or non-profits [119]. ... Furthermore, competition usually provides political institutions with greater information about the agency's behavior and performance. ... Second, even in the absence of direct competitors, many agencies face the possibility that some other agency could replace them in providing some, or all of their services, albeit perhaps at some net incremental cost to purchasers. Contestability or "latent" redundancy can provide incentives for an agency to change its strategy [123–125]. Many sub-national government agencies face quite credible threats of replacement [126]. In these circumstances, consumers can relocate and mobility functions as a form of contestability [127,128]. This is particularly pertinent if an agency has industrial consumers that are highly price (tax) sensitive. ... The conceptually important alternative competitive states that drive PASA are: (1) monopoly with little contestability; (2) monopoly, but with significant contestability; (3) competition from other government agencies or not-for-profits, and (4) competition that includes for-profit firms.
Political Influence Barriers: This distinguishes PASA from business unit analysis. Many legislative and executive branch entities seek to influence public agencies. Some of these attempts have some normative legitimacy, many others much less so. As with other external forces, agencies can seek to insulate themselves from influences [129,130]. They can do so if influence barriers can be altered by agency strategic actions. ... Generically, two factors are particularly important in determining the aggregate level of political influence barriers: the institutional ownership structure of the agency (the de jure property rights regime) and the permeability of the institutional ownership structure (the de facto property rights regime. For the purposes of external analysis, the focus is primarily on assessing the combined level and sources of influence barriers. Some agencies have constitutional or quasi-constitutional protection from political influence. In stable institutional environments, these formal barriers insulate agencies from overt political influence. In democracies, state-owned (SOE), mixed enterprises (private corporations in which government has some shareholding position) and "corporatized" entities [114,131] are endowed with quite high formal barriers to political influence. Line government agencies usually have lower formal barriers to political influence. Agencies that work directly for the executive or legislative branches have almost no barriers. In many countries, Quangos of various kinds have become much more prevalent [114]. Corporatization in the U.S. now encompasses a vast array of independent agencies. ... However, the institutional ownership structure alone is not the only factor determining political influence barriers. The formal barriers to influence are more or less permeable. Politicians, at various jurisdictional levels have a wide range of indirect methods to try and permeate, circumvent, or simply overpower formal ownership structure barriers to influence [133–135].
Four archetypes (generic agency or program types and level of autonomy): autonomous programs (with both high policy and fiscal autonomy), golden-handcuff programs (high fiscal autonomy, but low policy autonomy), poor-but-free programs (high policy autonomy, but low fiscal autonomy) and indentured programs (with neither policy or fiscal autonomy).
Autonomous Programs (e.g., Fed, FDIC, NCUA): Formal or de jure agency independence is an important precursor in almost all cases, whether as a corporatized entity or other form of autonomous agency or as a state-owned enterprise (SOE). ... These programs also tend to have high policy autonomy because the need for secrecy, the complexity of performance measurement, and the presence of significant isolating mechanisms all buffer them from most sources of political influence.
Indentured Programs (e.g., FEC): In stark contrast to autonomous programs, programs with both low fiscal and policy autonomy can be characterized as indentured programs. Such programs and agencies get their strategies imposed on them by others in their external environment and are likely to be characterized as ineffective. ... Even if the agency's mandate does not allow it to completely exit from a program, or executives do not want to exit because of the public value delivered, it may still wish to redeploy internal resources to programs with more autonomy
Poor_but-Free Programs (e.g., FDA, KDADS): Poor-but-free programs are often those providing programs and services to "unloved" users. These users include the homeless, the mentally ill, the incarcerated, the addicted, and the illegal. Frequently, both purchasers and other actors in the external environment dislike expenditures on these programs as they garner few kudos or votes, while attracting much criticism if anything goes wrong. ... A generic strategy for poor-but-free program executives is to seek to increase fiscal autonomy, while retaining the current degree of policy autonomy. This is a delicate task because the two autonomies tend to offset. Messing with fiscal

oversight tends to attract attention to agency policy and strategy. Strategies that lower costs along a program's value chain do not attract much external attention although they increase fiscal degrees of freedom [154,197].
Golden-Handcuff Programs (e.g., DoD, family planning): Golden-handcuff programs are somewhat unusual in that a high degree of fiscal autonomy normally also enhances the policy autonomy of a program's executives. However, policy freedom is formally constrained when agency or program legislative mandates are detailed and externally monitored [199,200]. Relative fiscal abundance occurs when powerful external forces are willing to bribe (and handcuff) agencies with high levels of resources or "blackmail" them by threatening to withhold or withdraw financial resources as the quid pro quo for policy and mission acquiescence. ... In spite of policy constraints, fiscal autonomy is valuable in its own right because it can empower some policy innovation, provided it is low profile and not controversial. Cost-lowering technological investment can fall into this category
Program and agency strategic choice (or more accurately, metachoice) should be constrained by a normative imperative: only consider, select and recommend those strategies that have potential to improve social efficiency. This is an important normative imperative because not all meanings of public value are close to equivalent to a social efficiency meaning: some meanings of public value fail this test and are not as normatively appropriate.
"Unorganized" or inarticulate members of the jurisdiction are given the same weight as organized interests (so called "stakeholders"). Ideally, the use of the social efficiency criterion (through cost-benefit analysis or practical substitutes where it makes sense) also balances the welfare of present jurisdictional members against those of future jurisdictional members (where long-lived investments make an intergenerational perspective the appropriate one).
PASA is most importantly a framework for agency strategic thinking rather than for strategic writing (not that there is anything wrong with the latter). External environmental volatility inevitably changes PASA

02 - Alexander Dawoody

Methods: Identification of agents as political paradigms to be positioned within nexus of complex and interconnected dynamics. Agents are units within matrix with interconnectedness (temporal, spatial) interpreted through metaphors based on complexity science themes; agents may influence own network of agents or other networks (potential for system dynamics feedback)

Results: N/A

System dynamics work if network of association is flexible, unrestricted, hierarchal, and adaptable. Public policy must act as a dynamically adapting system. Network is: transparent (inside and out), operates with mutual causality and influence, focuses on the present, seeks patterns and enables ongoing shifting, prepares for unexpected and uncertain, allows feedback, emergent properties.

03 - Ana V. Diez Roux

Methods: N/A

Results: N/A

A key characteristic of the types of population health problems for which complex systems approaches may be useful is the presence of influential positive or negative feedback loops
Another characteristic of population health problems especially suited to complex systems approaches is the presence of dependencies between individuals (i.e., situations in which the outcome for one individual is affected by the outcomes in other individuals). For this reason, infectious disease epidemiology has been at the forefront of the application of these methods in population health.28
A third characteristic is the presence of macro-level patterns that emerge from the interplay of factors at different levels of organization. In population health, interest often centers on understanding the factors that lead to differences in rates of disease across groups.
Systems approaches can help move the field of health disparities forward in 3 ways: (1) systems thinking can promote the development of more sophisticated dynamic conceptual models of the causes of health disparities, (2) systems tools (formal models and simulation) can help explore and refine these models and explore the effects of different interventions in the context of dynamic relations, and (3) the use of systems approaches can enhance the use of existing data and promote the collection of new types of needed data.
A major challenge is setting the boundaries of the system including the relevant time horizon and deciding which variables will be considered exogenous and endogenous, and what things will be

excluded. Defining the level of detail necessary in the model is key, and it may be necessary to consider submodels or subsystems linked to each other. It has been noted that, strictly speaking, model validation is impossible.25 However, researchers can do a number of things to enhance the credibility of their model for a specific purpose. Model building and checking is an iterative process that combines qualitative and quantitative knowledge of modeled processes, comparison of model output to various types of external data, and a number of tests and sensitivity analyses that can be used to identify flaws and improve models.25,60,61Pattern replication is often taken as a sign (although not necessarily proof) that the model captures basic underlying process relevant to the problem being studied. However, it is important to note that these models are not intended to be predictive models. The development and assessment of systems models is very different from the development and assessment of models used for prediction and forecasting. Model validation remains an active area of research and discussion within the systems field.
04 - Ana V. Diez Roux
Methods: N/A
Results: N/A
Although multiple definitions of systems and complex systems exist, key elements of systems include (1) the presence of factors at multiple levels of organization (e.g. city level factors related to governance, neighborhood factors such as environmental or social characteristics, various institutions and their organizational characteristics, families, and individuals); (2) heterogeneous units, be they individuals, institutions, neighborhoods etc.; (3) dependencies between units, e.g. norms being transmitted from person to person or neighborhoods close together in space influencing each other; and (4) positive and negative feedbacks (environmental policies influencing residential segregation and segregation in turn reinforcing environmental policies) 5,6,7. Acting together, these factors and processes result in the emergence of patterns that may not be easily understandable or predictable if one is not cognizant of the functioning of the system as a whole. Systems approaches go beyond the recognition that health is affected by distal factors or factors defined at multiple levels of organization, as has been the tradition in public health for a long time. They explicitly allow for dynamic processes including feedbacks as well as interdependencies and interactions between individuals and between individuals and environments over time. These feedbacks and interdependencies can result in non-linear relations and unanticipated effects distant in space or time. In going beyond the traditional emphasis on isolating the “independent” effect of specific factors to an understanding of the functioning of the system as a whole, the use of systems approaches implies a paradigm shift in the way in which population health is conceptualized, studied, and intervened on. "...but only recently have systems approaches garnered attention in other areas of health 10,11,12. Two important factors have contributed to this trend. One factor is the increasing frustration with traditional approaches used in population health research, essentially the randomized experiment and the use of observational data to approximate the randomized experiment to the extent possible...A second major factor has been increasing availability of the tools needed to build and simulate appropriate formal models of systems." One major implication of applying systems approaches to urban health problems (perhaps the most important implication) is the development of conceptual models of the processes leading to health in urban settings that explicitly incorporate dynamic relations, i.e. dependencies and feedbacks, as appropriate to the problem at hand. A major challenge in developing these dynamic conceptual models is setting the bounds and including only the elements fundamental to understanding the process at hand. A second implication is the need to employ new tools, specifically the development of a formal simulation model that can then be used to explore the functioning of system and the plausible impact of various interventions on the system. Third, the use of systems approaches also has implications for the ways we collect and integrate data. By definition, the development of a formal systems simulation model requires integrating various kinds of data, including both qualitative and quantitative data. Meaningful systems models allow us to understand the implications and consequences of various pieces of quantitative and qualitative information in ways that we would not necessarily have predicted if we did not do the formal simulation. Lastly, the use of systems approaches also has implications for the types of questions we ask, and

ultimately for the types of policies we can identify as important to improving health in cities. Debate by Gerard Salem (following article): Why? (overcome prior limits and highlight complexity of interrelations, interactions, retroactions); How? (define 'urban', 'health', complex interface between 'cities' and 'health'); What for? (help decision-makers, highlight interdependence, 'ecumenist approach') Debate by Marilia Sa Carvalho (following article): Systems thinking brings new breath to the recognition that in urban health we are not dealing with isolated factors that add up to cause disease, but as summarized by Ana, as an intrinsically complex situation with multiple levels of organization, heterogeneity, dependencies, and feedback. Related to (and as a consequence of) this complexity, I would explicitly include dynamic stability in the description of complex systems' characteristics 3, as one of the main aspects of unmovable disease trends cited above. Related to the same dynamic stability and inherent complexity, applying pressure at the right points – fulcrums – can bring down a complex system. Exploring scenarios based on either agent-based or full-fledged dynamic models is certainly a powerful tool for finding such fulcrums. ... The paper emphasizes an important point in using such techniques: "A major challenge in developing these dynamic conceptual models is setting the bounds and including only the elements fundamental to understanding the process at hand". Any mathematical or statistical model is limited to a few components. Simplification is not merely an option, but an absolute imperative. Thus, what is the gain in this approach if we are still constrained by very limited simulations? I think that the answer lies in the paper as well. The "systems approaches to urban health problems (perhaps the most important implication) is the development of conceptual models of the processes..."
05 - B. E. White
Methods: N/A
Results: N/A
III. CASE Activities: A. Attitude. B. Problem definition via soft systems methods (also see III.M, III.O, III.R). C/I. Risk mitigation and strategic action. D. Organizational change. E/O. Stakeholders, leadership, and decision-making/taking. F. Prioritization of outcomes. G/J. Management, resourcing, and performance management systems (incl. incentives); incentive structures facilitate self-organization and bottom-up efforts, discourage autocratic/hierarchal/top-down approaches, encourage informed risk-taking, instill career accountability. H. Consensus on boundaries, scope, and agreements. K. Stimulate self-organized collaborations which foster a spirit of cooperation and competition while maintaining trust. L. Establish a reference architecture for the complex system. M/N/Q. Identify and test interventions (including with stakeholders) but delay implementation. P. Modeling and simulation of behaviors (ABM). R/S. Implement interventions and monitor performance (including primary data collection). T/U/V/Y. Evaluate performance and adjust delivery of interventions; re-evaluate system (return to beginning). W/X. Reward and promote success.
06 - Barry Bozeman
Methods: N/A
Results: N/A
This paper (1) considers the costs and the foregone opportunities resulting from this mutual intellectual disregard, (2) presents an illustrative case to show the possibility of cross-fertilizing public policy and organization studies, and (3) suggests some general strategies to promote cross-fertilization between these two apparently related fields of inquiry. health and human service policy (Huang & Provan, 2007; Provan, Isett, & Milward, 2004) Scholars in the sociology of science have provided insights into the developmental trajectories of academic fields (for overviews see Becher & Trowler, 2001; Messer-Davidow & Shumway, 1993; Whitley, 1984). We know from this literature (Barnes, Bloor, & Henry, 1996; Merton, 1973) that new

fields and disciplines develop in quite diverse ways but often having the same objectives, including legitimation, prestige, and access to resources.
Simply stated, the idea of policy implementation is that the policy cycle is not concluded when policy is designed. Policies must be implemented and the quality of implementation has much to do with policy effectiveness.
The central idea behind the dimensional publicness theory is that, rather than thinking of public and private organizations as distinctly different, differentiated by their respective sectors or legal status, it is often more useful to think of all organizations as being influenced by both external political authority and external economic authority (Bozeman, 1987). Political authority is usually but not always associated with government and private authority is usually but not always rooted in markets. The dimensional publicness model holds that public and private are dimensions, not dichotomies, and that much can be learned by knowing the particular mix of political and economic authority affecting organizations. According to the dimensional publicness model, some organizations are “more public” or “more private” than others and even business firms may be compared on their degree of publicness, just as government agencies can be compared on the basis of their privateness. In at least some cases, particular government institutions may be “more private” than particular business institutions and, likewise, particular business institutions may be “more public” than some government institutions. In the case of hybrid organizations, such as public authorities, multi-organizational consortia, and such, the classification as government or private is essentially fruitless; in some cases it is only the political and economic authority mix that gives us much purchase on the factors influencing the organization’s behavior (Emmert & Crow, 1988).
The causal mechanics of dimensional publicness theory are straightforward: organizations subject to constraints of political authority or dependent on political authority for resources behave differently owing to the “imprint” of public ties. This imprint usually involves a more intensive regulatory environment, increased accountability, and perhaps increased “red tape,” more extensive political oversight, and greater public visibility. Less public organizations tend to be sheltered from these constraints and maintain a higher degree of autonomy in both strategy and action.
Our objective was to develop a typology based on R&D organizations’ locations on dimensions of publicness and privateness (illustrated in (Table 1, adapted from Crow and Bozeman [1998]) and to use the typology to predict organizational effectiveness.
Dimensional Publicness promotes cross-fertilization due to: dimensional publicness deals with elemental phenomena; it clearly includes both empirical and normative questions; and the internal working of the theory contrasts public spheres and private spheres and, unlike related theoretical apparatuses in economics, does not privilege one type of authority (political or market) over the other
Studies of disciplinary cross-fertilization provide another set of guideposts based less on bibliometric models than on organization and group norms. Some (Matthiasson, 1968; Miller et al., 2008; Reich & Reich, 2006) argue that interdisciplinary collaboration and cross-fertilization require a sort of “cultural competence,” including a capacity for assessing the particularities of one’s own disciplinary culture, its hierarchies and social control mechanisms and projecting how these dynamics might affect the perceptions and biases one brings to collaboration.

07 - BD Jones, FR Baumgartner

Methods: Eq1. Incrementalism via central limit theorem (changes from status quo follow normal distribution): Pt = Pt-1 + et; Policy today (Pt) is policy yesterday (Pt-1) plus or minus a random component.
Eq2. Incrementalism with upward drift (normal distribution trending up): Pt = [1 + k]Pt-1 + et => (Pt - Pt-1)/Pt-1 = k + w, where w = et/Pt-1; k is a constant proportional growth increment
Eq3. Implicit index model (weighted average of indicators): Lt = w1tI1t + w2tI2t + . . . + wktIkt + gt; where Lt is the value of the index at time t, Ikt is the kth indicator of the state of the world, wkt is the weight for the kth indicator, and gt is a random error component.
Eq4. Model for updating prior beliefs (from implicit index): Dt = kLt - Dt-1 + jt; where Dt is the decision at time t, Dt-1 is the decision at time t - 1, jt is a random component, and k is just a constant to adjust the units of the index to the units of the decision.
Frequency distribution following Eq4 & Eq4 may not be normal, as in incrementalism
We may show this by using a simple simulation. We have drawn a sample of 10,000 random digits for five different variables.4 These will serve as the indicators of problems facing government.

We have applied five different nonlinear transformations to the five simulated random variables.[5] Then we summed the five variables and prepared a histogram similar to that diagrammed in figure 1, the budget change histogram.
We may simulate this disproportionate response process in a manner similar to our simulation of proportionate information processing. We again generated 10,000 random numbers each for five separate nonnormally distributed variables. This time, instead of weighting each one equally, we gave one indicator a weight of 0.8, and the rest were weighted at 0.05.[6] Then we summed the weighted indicators and plotted the results as shown in figure 3
Eq5. Model of Competitive Economy: R = bS; where R = response dO = change in output, S = information (signal), and b = benefits derived from the information flow (<1).
Eq6. Model with costs acting linearly: R = bS - C; where C = costs.
Eq7. Model with costs interacting multiplicatively: R = bS x C
Eq8. Model with response delay (signal arbitrarily cubed): R = bS3.
simulation for the case of a uniform input distribution in order to get a firmer understanding of just what the transformations do. This is a kind of limiting case in which the world has some uncertainty but may be monitored by one indicator, and that indicator is uniform and unchanging. We generated 10,000 random numbers drawn from a uniform distribution with a mean of 0 and a standard deviation of 1. We cubed these numbers once and cubed the resulting numbers once again. Then we made frequency distributions for all three sets of 10,000 numbers. The input series, being uniform random, has a strongly negative kurtosis value (e.g., it is platykurtic rather than leptokurtic).
Simulation of diverse input streams combined to yield index or sum of indicator values with two sequential cube transformations.
Dynamic computer simulation with components (policyagendas.org): signal (input), friction mechanism (threshold which dampens response), error accumulation (pressure leading to response), response (dictated by input and friction); variables of signal and response and three parameters for friction and response.
Eq9. Dynamic Model: Rt (St + sum(S0<k) >C) = bSt, Rt (St + sum(S0<k) <C) = lbSt; where variables Rt = response, St = input signal; where parameters C = friction parameter, l = efficiency parameter, b = amplification parameter; and where 0 < l > 1 (l may vary between 0 and 1), 0 < t > k (the time series goes from period 0 to period k), and St = N(0,1) (each input signal is drawn from a standard normal distribution).
Results of our hypothetical policy-making system that has run for a million time periods are input into a frequency distribution

Results: It is evident that the distribution [from the simulation] approximates the normal distribution, and statistical tests indicate that it does not differ significantly from the normal. This is in many ways an astounding result, because of the limited number of variables we included and the very nonnormal shapes of each of the underlying indicators.
In general, if government makes policy according to equation 3, then the outcomes would be normally distributed.
We have analyzed decisions on a single policy topic, but a similar model holds among topics. Political leaders typically must juggle numerous policy topics, investing attention in a one-at-a-time manner. This juggling involves overattention to one area as all are changing. The result is an outcome distribution across policy areas that is leptokurtic.
The converse of these propositions is also true: normal output distributions invariably indicate incremental decision making with proportional updating, and leptokurtic output distributions are characteristic indicators of disproportionality in the choice process.
Simulation for Eq 8. The first cube law transformation yields a kurtosis of 3.70, slightly more than the normal, while the second's kurtosis is 9.73 and is leptokurtic. Even in a hypothetical uniform world, nonlinear cognitive and institutional costs will yield leptokurtic output distributions. Simulations for combination of input streams: Again the distributions are highly leptokurtic, with the first transformation producing a kurtosis of 36.30, and the second, 977.44. In both of these two important cases for the distribution of information coming into a policy-making system, outputs will be leptokurtic when costs are nonlinear. Much more important, however, is the fact that the leptokurtosis increases disproportionately as the costs move from cognitive costs alone (the first cube law transformation) to cognitive costs and institutional costs (the second transformation). This happens regardless of the input distribution—the ordering of the distribution by extensiveness of cost imposed leads to a parallel

ordering of the magnitude of kurtosis. Dynamic simulation (Eq9.): for appreciable friction, output distributions are invariably leptokurtic. Numerous runs of this simulation yield leptokurtic output distributions Clearly institutional friction is capable of producing policy output distributions consistent with what we observe empirically. Nevertheless, there are some differences; the simulated graph is not as leptokurtic as the actual data, which have both a more concentrated central peak and fatter tails. In effect, institutional friction (at least the way in which we have modeled it) cannot fully account for budget distributions. This is almost certainly due to the exclusive focus on friction in the model, with no provisions for positive feedback and cascades, and the assumption that cognitive costs are unimportant. The stronger the friction, the more punctuated the policy output. Kurtosis is a function of both the threshold C and the extent of partial response—leakage through the threshold. As the threshold increases, kurtosis increases exponentially (note the log scale). When little leakage occurs with a high threshold, kurtosis is exceptionally large—most of the cases represent no change, but a small number of really big punctuations occur. When the leakage around the institutional friction reaches a maximum (at l51), the level of the threshold is irrelevant, and kurtosis for all values of the threshold equals 3, the value for the normal input distribution.
It is the purpose of this article to offer such an alternative, one that shows how incrementalism is a special case of a generalized updating model we term disproportionate information processing. It is also the foundation for punctuated equilibrium, so it unifies incrementalism and punctuated equilibrium within a single decision-making model. Incrementalism failed because it had no underlying theory of information processing; once one is specified, the rest is easy. The notion that decision makers make incremental course corrections from the status quo has dominated thinking about policy change since the late 1950s. The incremental model as a descriptive model of policy choice has been subject to withering fire on theoretical, methodological, and empirical grounds, all profound criticisms that it did not survive. Critics have noted problems in the models used by Davis, Dempster, and Wildavsky (Gist 1982; Natchez and Bupp 1973), in the measures used (Wanat 1974), in the conceptual clarity of terms (Berry 1990; Hayes 1992), and in the nature of the underlying decision-making model (Padgett 1980, 1981). Others have complained of problems in capturing the complexities with simple theories of budgeting, particularly the incremental model (Kiel and Elliott 1992; Rubin 1988; Schick 1998). While the incremental model was discredited by these critiques, it was never replaced by a viable alternative. Incremental decision-making reasoning: ease of reversing incremental mistakes, stability in governance over time, prioritization toward compromise An examination of empirical budget distributions shows that they are never normally distributed. The typical pattern is clearly leptokurtic. The pattern is general, and the implication is clear: public budgeting is not incremental. What is to be explained is the leptokurtic distribution of changes. In all of these and many more situations a decision maker explicitly forms an index out of numerous, often noisy sources of information and keys future choices to the value of the index. But decision makers invariably are producing implicit indicators on virtually every choice they make. The central limit theorem implies that if we weight and sum enough indicators, regardless of their distributions, so long as the weights are not terribly different from one another, the sum will be normally distributed. Rational adaptation, in the sense of combining several indicators, each of which may be fallible and skewed itself, will lead over time to a normal distribution of responses to the problems that government faces. If the weighted indicators were normally distributed, then the weighted series would be closer to normal. But a decision maker relying on a single indicator whose distribution was normal would be just ‘‘getting lucky,’’ because there is no statistical reason (or empirical reason that we can discern) for assuming that an arbitrarily chosen input stream would be normal. Decision-making systems impose four kinds of costs in making decisions in response to a changing environment: decision costs (costs to setup arrangement), transaction costs (costs following agreement), information costs (costs to obtain information), and cognitive costs (costs to process information). The cube law and other upward-turning, convex curves model this kind of general process [attention

allocation and general bias toward status quo]. It is also possible that cognitive costs act to cause immediate overreaction and then a dampening down of response. This would be modeled by a concave curve, such as the logarithm or a power function under 1.0.
In general, the dynamic simulation supports our general argument here that the interaction of cognitive factors with institutional friction invariably leads to a pattern across time of general stability with episodic punctuations. And our simulations allow us to show that with friction set to 0 or leakage set to its maximum, there is no punctuation at all. So we believe there is something important in these parameters that explains the punctuated equilibrium patterns that we observe in the real data.
As all government institutions impose costs, we expect all outputs from them to show positive kurtosis. As decision-making costs increase—that is, as it is more difficult to translate informational inputs into policy outputs—the more leptokurtic the corresponding output distributions. We term this the general punctuation hypothesis. We have tested this hypothesis and have found very strong evidence in its support (Jones and Baumgartner in press, ch. 7; Jones, Sulkin, and Larsen 2003). Kurtosis increases as the (implied) institutional friction of the process increases.

08 - Brian W. Head, John Alford

Methods: N/A

Results: N/A

Authors decompose challenging features into nuanced categories.
General critique from systems theory (problems interact in a system of problems); social policy/professional education critique (social issues grounded in value perspectives; planning/design critique (modern society is pluralistic vs homogeneous and not amenable to top-down engineering solutions)
10 characteristics of wicked problems (see article)
Heifetz (1994) Typology of Problems: Type 1 (technical): clear problem and clear solution; Type 2 (adaptive): clear problem and unclear solution; Type 3 (wicked): unclear problem and unclear solution
Tackling adaptive-wicked problems best via adaptive management and networked governance
Public-sector management complicates due to piecemeal overlay of new policies and operations over time; hierarchal administration focuses on input monitoring and process compliance; New Public Management (NPM) ill-suited to deal with wicked problems due to intraorganizational/managerialism/corporate management and contractualist focus leading to fragmentation
Broader ways of thinking of variables/options/linkages: frame reflection (value and perspective shared narrative), systems thinking, complexity theory; collaboration-coordination (CJS/CSC/intragov., cooperative-coordinative-collaborative); Collaborative advantage: better problem definition, better solution identification, better intervention
Conclusions: efforts to deal with wicked problems are impeded by the working mechanisms of the public sector—its characteristic ways of making decisions, organizing, financing, staffing, and controlling; strategies for dealing with wicked problems under these governmental and administrative constraints—such as going beyond technical/rational thinking, collaborative working, new modes of leadership, and reforming the managerial infrastructure of government

09 - Charlan D. Kroelinger, Kristin M. Rankin, David A. Chambers, Ana V. Diez Roux, Karen Hughes, Violanda Grigorescu

Methods: N/A

Results: N/A

Complex Systems Thinking: Programs and interventions have increased in complexity over time and evaluating the impact of these multidimensional programs requires a broader framework than has traditionally been used [1, 2]. Complex systems thinking explicitly acknowledges the presence of multiple levels, feedback loops, and dependencies (such as individuals influencing and affecting each other). Multiple levels of influence, feedback loops, and dependencies result in the emergence of macro-level patterns [3]. A more thorough understanding of the dynamic relationships in the system [3] may help anticipate and monitor the effectiveness of a program or intervention over time. ... initiatives to improve the physical environments could result in a reinforcing feedback loop that triggers further beneficial changes in the environment. Feedback loops may be reinforcing or buffering and may result in unanticipated smaller or larger impacts on health outcomes than expected, and effects on other factors that could potentially influence health outcomes

Implementation Science: The term ‘implementation science’ is defined as the communication of evidence-based, effective approaches to affect change in clinical or programmatic practice, to ultimately impact health outcomes. ... Implementation science can be contextualized as a part of a broader translational research pathway, which extends from the discovery of new scientific information to the testing of interventions that can arise from that discovery, and then the movement through systems, policy, and improvement in population health. ... implementation science as a discipline supports identification of attributes that allow for iterative changes and adaptation to impact health outcomes. ... The ultimate success of implementation science is strongly determined in the initial phases of scientific discovery (P1-testing, P2-research impact, P3-research into adoption, P4-evaluation)
10 - Christina Seidel
Methods: Reviews of existing literature and case studies as well as interviews with key public policy individuals
Results: Barriers to applying LCA to public policy: decision-makers lack background or technical literacy; technical results not presented in way to be positively utilized; decision-makers have lack of trust in LCA results or process,: lack of clear or consistent outcomes; LCA results not seen as neutral; governments lack framework for integrating LCA into decision-making process; government may limit scope due to competing interests; comprehensive public LCAs may require considerable resources; complete and accurate inventory data may be difficult to obtain Discourse Theory may be a means to overcoming barriers SETAC priorities for incorporating LCA in public policy: ensure stakeholder involvement occurs early and throughout process; encourage strong partnerships among stakeholders; document and ommunicate LCA application; encourage LCA use; educate policymakers on concept and use of LCA IAPP Core Values: involve decision-makers and stakeholders in LCA process; translate values and limitations of LCA concepts and methodologies; provide case studies of successful LCA in public policy; present assumptions and uncertainties transparently; ensure a diverse project team (balance interests) One of the conclusions of the reviewers was that more time should be spent on the conclusions and interpretation of results for a non-technical audience, to provide more information for policy makers (CalRecycle 2014). This reinforces the importance of being able to present the results of an LCA in a format useable by policy makers.
Two theories for development of public policy: Discourse Theory, Rational Theory Discourse Theory: need for open and inclusive process for stakeholders to learn of each other's perceptions with a focus on communication and understanding; LCA supports and stimulates discussion Rational Theory: emphasizes quantification and objectivity with technical information as the key factor; LCA may provide relevant information in a comprehensive way LCA may contribute to problem identification, policy implementation, and policy evaluation stages LCA results depend on methodological choices made during the process, which are influenced by the values and perspectives of the practitioner and commissioner of the study (Ekvall et al. 2007). The use of LCA within a public policy framework is more complex than other applications in that the decision-making process itself is more complex as a result of the multiple players involved, bringing diverse interests, viewpoints, and backgrounds (Bras-Klapwijk 1999). Public policy decisions vary greatly, from narrow mandates to broad policies, and involve a wide range of institutions, from local municipal departments to federal agencies. As a result, the way LCA is applied within the public policy process can and should be different, based on its audience (Allen et al. 1995). This recognizes that, despite the value that LCA can add to the decision-making process, a full LCA (as represented on the quantitative end of the continuum) may not always be an appropriate addition to a public policy development process. In cases where resources, including both funding and time, are limited, LCA may simply not be a viable option. LCA offers a valuable tool for assessment of the full environmental impacts of public policy options involving product or process choices, and facilitating its increased application in the public policy arena could improve the decision-making process and ultimately lead to better environmental outcomes.
11 - D Hunter, N Perkins

Methods: Research Stage 1: systematic review (published separately); Research Stage 2: case studies (on-site KII, telephone KII, focus groups on tracer issues) "Public Health Partnerships" not defined too restrictive and fall into one of three categories: facilitating partnerships (manage long-standing strategic policies); coordinating partnerships (managing and implementing prioritized policies), implementing partnerships (pragmatically managing and implementing specific mutually beneficial projects) Facilitating partnerships include local strategic partnerships (LSPs)-may be replaced by Health and Wellbeing Boards (HWBs)-and local area agreements (LAAs) which balance central government and local government priorities for area-based funding
Results: Determinants: partnership that is clear about its goals and objectives, partners aware of roles/responsibilities, partnership that has a clear strategic overview of performance via monitoring and evaluation Barriers: differences in priorities, power imbalance, lack of interdependence, lack of information sharing (leads to duplication with users being re-assessed by a succession of separate services), lack of cohesive user-centered approaches (leads to loss of responsibility when single service is completed but user requires more), absence of vertical linkages (leads to disconnect between strategic level (e.g., LAA) and frontline) Partnerships & LAAs: joint delivery plans must be aligned with LAAs (difficult to achieve) Partnerships & Outcomes: policy and procedure seen as overly bureaucratic (leading to time delays, increased process-focus, and decreased outcomes-focus); "how ar we doing?" rarely asked and rarely answered Relationship with UK gov: top-down approach not preferred by locals
Public health partnership research (2007-2010) had 3 aims: context (clarify factors promoting effective partnership working for health improvement), process (assess extent partnership governance and incentive arrangements are commensurate with problem complexity), outcomes (assess local partnership contributions to better outcomes via tracer interventions) Partnerships still rooted in silo-based structures governing organization and delivery of services; often designed to avoid loss of power vs pooling power/resources so that the whole becomes greater than the sum of the parts; need to design partnerships to address the problems being faced Lessons from Research: policy and procedures need to be streamlined with emphasis on outcomes (outcomes focused policies, joint delivery mechanisms, clear accountability, engagement of relevant partners, careful monitoring); strategic-level leaders may learn from frontline approaches and alignment; need to establish causal relationship between partnership joint operations and partner individual outcomes; enhance focus on purpose, achievement, and monitoring instead of structure/bureaucracy; relational factors (e.g., trust) is more important than structures; adaptive leadership; complex systems thinking to address wicked problems Partnership Rules: clear purpose, common aims/goals/objectives; right partners with accountability; honest dialogue of partnership contributions; investment in building trust and relationships; adaptive leadership which works across silos
12 - D Young, R Borland, K Coghill
Methods: N/A
Results: N/A
ANT is a broader umbrella theory that can explicate all 4 stages; it encompasses Westfall et al.'s27 extended US National Institutes of Health (NIH) categories—translation 1 (basic science to trials), 2 (trials to practice) and 3 (practice-based refinement)—and uses concepts and strategies associated with the more focused theories in doing so. As explained in the following sections, ANT provides a theoretical framework for understanding, and a guide to the prerequisites for, successful change in complex systems; in this case, through policy innovation. ANT focuses on science-based innovation processes, and, in analyzing indoor smoke-free regulations, the process necessitates engagement with all the component subsystems (tobacco control, tobacco industry, regulatory, and tobacco use) of the tobacco use management system2 as well as relevant features of their context that together determine tobacco use. ANT argues that fundamental system change requires that actors and resources are ''translated'' 5(p106–109),30 away from their formal subsystem roles and that a network grows as they join with others, outside the

system, to pursue the innovation. ANT describes a process in which heterogeneous elements are woven together and assembled into reality. This move beyond ‘‘social networks’’ and ‘‘social diffusion’’ represents a fundamental ontological contribution by ANT. The central core, or ‘‘links and knots,’’ represents the actors (knots) and the set of relationships between them (links) that first initiate the innovation and then act to organize, and hold in place, all the activities along the 4 ‘‘loops’’ that reach out into the broader context. In evidence-based innovation, the loops represent activities designed to link the core with 4 interdependent sources of power: scientific evidence and the technologies or techniques that depend on it, professional or political authority, allies, and public opinion. Loops: Mobilization (data and communications) - net contribution of science provides certainty ("immutability") and generalizability ("mobility"); Alliance Building (coalitions) - primary focus on supportive alliance members while groups with secondary interests are vulnerable; Public Engagement (political capital) - solutions often a balance of interests; Autonomization/Institutionalization (governance, policy, investment) - assuring defensible solutions that may be easily adopted with few compromises or unintended consequences Stages: Stage 1 - Autonomization (defining problem as autonomous issue); Stage 2 - Problem-Solving (debate, policy innovation); Stage 3 - Resolution We argue that the most effective solutions to complex problems emerge where collaboration facilitates strong actor-network development. More effective regulatory frameworks can be developed by institutionalizing this collaborative imperative, especially where scientific discourse is critical to decisionmaking.13 Employing collaborative, deliberative processes requires one caveat. All actors who can envisage a non–zero-sum solution need to be brought to the table, but actors whose goals are intrinsically antithetical to a problem’s definition (let alone resolution) should be excluded. However, in the case of product regulation to reduce harmfulness, a partial convergence of interests could provide the basis for progress ANT is not a predictive tool; it is a descriptive tool that takes into account the many varied elements contributing to innovation and facilitates understanding of the reasons for success or failure in different contexts. It is also an extremely powerful planning tool, identifying the links necessary for policy innovation to occur. Applying the ‘‘links and knots’’ model, following a systems analysis, enables planners to move seamlessly from ‘‘what’’ to ‘‘how.’’ There have been some attempts to employ quantitative techniques to model actor networks. These include early work on ‘‘sociotechnical graphs,’’72 and more recently the development of the analytic technique known as Reseau-lu,73 that is specifically designed to model heterogeneous networks. The strength of the approach presented here is that, informed by a socioecological model,1 the more focused actor-network model articulates the full process of innovation. Rational change does not emerge spontaneously. It needs to be framed from a strategic perspective, encompassing all identifiable influences (social–ecology framework) and enacted via sociopolitical processes (facilitated by ANT analysis).
13 - Douglas A. Luke, Katherine A. Stamatakis
Methods: System dynamics (SD): uses informal and formal models with computer simulation to uncover and understand endogenous sources of complex system behavior Network analysis (NA): the measurement and the analysis of relationships and flows among actors, including people, organizations, and other information processing entities Agent-based modeling (ABM): uses computer simulations to examine how elements of a system (agents) behave as a function of their interactions with each other and their environment
Results: Case Study 1 (infectious disease): Models of Infectious Disease Agent Study (MIDAS) as collaborative ABM modeling network used to simulate outcomes of potential infectious disease policy and practice decisions; SD models also in use Case Study 2 (tobacco control): National Cancer Institute's Initiative on the Study and Implementation of Systems (ISIS) is SD causal map of complex feedback loops between various actors used to explore the additive and interactive effects of multiple policies and interventions on smoking; SimSmoke SD models used to explore potential effects of tobacco-control policies; ABM has not yet been used to

study tobacco-control Case Study 3 (obesity): complex systems models (e.g., COMNet, CompMod, Foresight) offer a set of analytical methods that can account for causal complexity; NA-SD-ABM used in simulations
Complex Systems: made up of large number of heterogeneous elements, elements interact with each other, interactions produce emergent effect (different from effects of individual elements), emergent effect persists and adapts to changing circumstances PH science dominated by randomized control trials (RCTs) and epidemiologic risk factor studies (quasi-experimental); both focus on internal validity and precision of measuring intervention effects but neither focus on external validity or contextual/ecological effects; RCTs and risk-factor designs randomize (ensures study participants not from naturally existing social/organizational systems and excludes respective behavioral effects); RCTs and risk-factor designs aim to identify existence/magnitude of effect/relationship but not the mechanism of effect McGrath's 3-Horned Dilemma: generalizability to population, measurement precision for behavior, realism of context of behavior High-level aggregate models (such as SD) have been useful for forecasting long-term population-level trends but less useful in identifying important mechanisms or relational structures as drivers/influencers; NA has proven more successful and may address how social networks influence individual behavior and how local/state/national systems are structured
14 - Edward H. Ip, Hazhir Rahmandad, David A. Shoham, Ross Hammond, Terry T. -K. Huang, Youfa Wang, Patricia L. Mabry
Methods: Statistics and statistical models refer primarily to Null Hypothesis Significance Testing (NHST) employ a generality-realism-fit-precision paradigm motivated by the work of population biologist Richard Levins (1966) and later expanded by other biologists (Matthewson & Weisberg, 2009; Odenbaugh, 2006; Weisberg, 2006), which we referred to as the Levins Framework. Briefly, our framework considers four attributes, or desiderata of models: generality, realism, fit, and precision. We present different modeling applications as each representing a different balance, or what we shall call set of tradeoffs, between the four desiderata. Levins Framework: precision ("fineness of model specification"), realism (qualitative predictive accuracy of model and accuracy to reality), fit (quantitative predictive accuracy of model and accuracy to reality), generality (extent model can be applied across circumstances/phenomena) Comparison of statistical models, ABM, SD models
Results: see Table 1 and Table 2
SS Methodologies to address a range of goals, including: (1) Knowledge Synthesis (summarizing information across a range of domains to represent the “big picture” view of the system or problem); (2) Heuristic (to aid in understanding the dynamics underlying the system or problem); (3) Hypothesis Generation (to generate new hypotheses and/or narrow the list of plausible hypotheses); (4) Forecasting (to generate a range of plausible future scenarios, based on explicit assumptions); (5) Identify and Prioritizing Research Gaps (use sensitivity analysis to determine knowledge gaps that, if addressed, would narrow the confidence band associated with model outcomes); and (6) Virtual Experimentation (conduct experiments in silico, saving time and money). SS Methodologies employed for: policy analysis and design—to examine tradeoffs of implementing different policy options; to generate and test dynamic hypotheses—could the Behavior X be generated by Causal Structure Y (i.e., a set of causal relationships); for anticipating future behavior modes—what is the expected future trajectory of variables of interest under specified conditions; and when exploration is the goal—what system behaviors (some of which may be unanticipated) emerge from dynamic simulation. Systems science models often rely on the conceptual framework and heterogeneous qualitative and quantitative data sources, and the consistency of the data may not be comparable to the sort of data that are demanded by statistical approaches. Furthermore, systems science models often emphasize generative explanation and emergent behaviors of systems whereas statistical models focus on the notion of causality (e.g., in clinical trials) and consistencies of models with carefully collected data sets from designed experiments and empirical studies. Therefore, a systems modeling choice that seems like a poor practice to a statistical modeler may be motivated by the pursuit of goal different from what the statistical modeler is used to, and vice versa.

For example, some models may target point prediction, and others may seek insight generation, descriptive accuracy, hypothesis testing, relevance to policy questions, or other goals (Randers 1980). Appreciating these differences in modeling goals and approaches is crucial for communication across disciplinary boundaries and for increasing consistency among policy conclusions that emanate from model-based analysis (Andersen, 1980).
15 - Emily F. Gates
Methods: SR in 3 phases: Systematic Selection, Coding, Thematic Analysis Systematic Selection: search (academic & gray, relevant fields, search terms, 1988-2015); inclusion/exclusion criteria (STCS focus, exclude non-evaluation articles, exclude articles lacking discussion on specific evaluation method or approach, other exclusion criteria) Coding: NVivo used; categories of Main Argument, STCS Ideas/Techniques, Primary Field Thematic Analysis: analysis by 6 core evaluation activities framework
Results: Systematic selection: twice as many articles reviewed from non-evaluation fields (most excluded because not focusing on the same systems or on evaluation) Coding: 1st 3 core evaluation activities of framework coded 2x more than the 2nd 3 core activities (less conversation) 1) supporting social problem solving: evaluators and evaluations can no longer implicitly and unreflectively make assumptions about social problem solving, regardless of whether these assumptions predominate in the evaluation field. Instead, evaluators should explicitly and critically examine assumptions made by those planning and implementing social interventions. Furthermore, those interested in using STCS in planning, implementing, or evaluating an intervention may want to purposefully work towards the second approach to social problem solving. 2) framing an intervention and its context: STCS Interventions: 1) characterized by levels of complexity, 2) a system (or subsystem), 3) a complex adaptive system, 4) an agent to change a system, 5) a situation of human activity, 6) a space for innovation and adaptation, and 7) a complex causal process; STCS Context: 1) real-world system(s), 2) the problematic situation addressed by the intervention, and 3) a constructed reference system(s). 3) selecting and using methods: Method selection and the situation of application are interdependent such that selection of a method informs how the situation of application is understood and any understanding of the situation will inform which methods are considered relevant and applicable. The main implication of this interdependence is that evaluators must be thoughtful and cautious about the practical and ethical consequences of methods selected for their influence on the way a situation is understood 4) engaging in valuing: In short, value judgments differ across time period, level of analysis, purpose, and perspective taken among other factors. STCS suggests another way of making value judgments that can, at least somewhat, account for the instability and conditionality of value judgments. Another consideration with regards to valuing is that some approaches within STCS, particularly critical systems heuristics, suggest making value judgments by constructing descriptive (what is) and normative (what should be) models of an intervention and comparing these models. These models can be developed based on social science or systems theory (e.g., viable systems model of organizational functioning), computer simulation (e.g., systems dynamic model of a causal theory of change), or stakeholder deliberation (e.g., conversation about what is happening and what should be happening in an intervention). Models differ from criteria in that they address multiple dimensions in relationship to one another; include ways to weight or prioritize different dimensions; assess an intervention within a specified context; and are open to ongoing revision. However, criteria can be selected based on these models to render a criterion-based judgment. As valuing was the least discussed issue, the main takeaway here is that further conversation and research are needed to more fully examine the implications of STCS for valuing. Moreover, different traditions within STCS explicitly acknowledge and address values to varying extents. Further examination should focus on traditions and approaches that explicitly deal with values and the making of value judgments such as soft systems methodology, viable systems modeling, and critical systems heuristics. 5) producing and justifying knowledge: In summary, STCS provides ways of examining causal processes within interventions and within the broader contexts in which social interventions are located. These rely on ways of thinking about causality that are unfamiliar to most evaluators.

Furthermore, STCS offers an expanded way to use models for learning and provides opportunities for incorporating theoretical and hypothetical data into constructing and justifying knowledge claims. 6) facilitating use: By facilitating use in one or several of these ways using STCS, evaluators can expand the role of evaluation in an intervention and in the broader organization or institution in which the intervention is embedded.
New Evaluation Methods: Developmental Evaluation (Patton, 2011), Systemic Evaluation (Boyd et al., 2007), Systematization (Tapella & Rodriguez-Bilella, 2014) Modified Conventional Methods: Responsive Evaluation (Gregory, 1997) and Theory-based Evaluation (Callaghan, 2008; Davies, 2004; Hummelbrunner, 2010; Rogers, 2008; Stame, 2004). Influences on evaluation practices: 1) supporting social problem solving; 2) framing interventions and contexts; 3) selecting and using methods; 4) engaging in valuing; 5) producing and justifying knowledge; and 6) facilitating use. Implications for STCS: First, rather than view systems as ontological phenomena occurring out there in the world (e.g., school systems, health care systems, ecosystems), I regard systems as social and epistemological constructs that people use to understand complex situations. Rather than view STCS as a set of ideas and methods for thinking about systems, I approach STCS as a way to understand and act in an inevitably complex social world. Second, systems and complexity thinking are enhanced by the use of tools, methods and approaches from the systems and complexity fields. In other words, I think systems and complexity concepts (e.g., boundaries, emergence) are more valuable when understood and used within particular systems and complexity approaches or methodologies. Third, the rich diversity of traditions, theories, and approaches within the systems and complexity fields needs to be acknowledged and embraced by evaluators. While I personally am most familiar with critical systems thinking, I believe that the evaluation field has much to learn from the many traditions. Fourth, the greatest value of STCS extends beyond the evaluation field and the task of evaluating social interventions; it has relevance for the design, planning, and implementation of social interventions and, more generally, for management of social change processes and institutional governance. Fifth, and perhaps most importantly, STCS should not be considered to be relevant to only some evaluation purposes and contexts and types of social interventions; rather it is relevant to and has value for any evaluation purpose and context. These ideas informed the way I reviewed and interpreted the conversation about STCS in evaluation. Viable Systems Model (VSM) (Hoverstadt, 2010) presents a diagram of the organizational structure and processes necessary for any system to meet the demands of surviving in a changing environment. Viability is the overall normative aim with many dimensions (e.g., variation within an organization matching variation in the environment) that together can be compared with a descriptive analysis of an organization in order to generate a value judgment of the organization and directions for future action. Critical Systems Heuristics (CSH) that can be used to descriptively and normatively examine four sources of influence on an intervention (i.e. sources of motivation, control, knowledge, legitimacy) (Reynolds & Williams, 2011; Reynolds, 2007; Ulrich & Reynolds, 2010). Implications: STCS requires shift from linear PDSA; multiple framings needed beyond strictly descriptive approach; underlying assumptions need review; STCS may influence value judgments of social interventions; STCS approaches presume dynamic causality which requires understanding and modeling causal relationships; STCS allows for opportunities to embed evaluation into intervention Shortcomings: there has been little discussion about how evaluations that are primarily conducted for public accountability purposes demonstrating the effectiveness and costeffectiveness of public programs might benefit from incorporating STCS. Second-order cybernetics: focuses on feedback, communication, visualization Dialogic design science: technology-supported collective discussion and decision-making
16 - Eric Silverman
Methods: N/A
Results: N/A
ALife is thoroughly steeped in the language and conceptual frameworks of complex systems, and many of our approaches and models incorporate interacting layers of agents, environments, and processes. Terms that are slowly entering the population health discourse include foundational ALife concepts like emergence and adaptive behavior.

Currently the population health landscape is shaped largely by reductionist statistical approaches, carving complicated problems into manageable chunks that can be turned into actionable policy solutions. As we have seen, however, these linear approaches to complex, nonlinear problems can produce policies that are ineffective or even counterproductive. By demonstrating the benefits of modeling populations as multi-layered complex adaptive systems, we can start changing the lens through which society is viewed by policymakers, and in the process develop more effective solutions.
17 - Gemma Carey, Eleanor Malbon, Nicole Carey, Andrew Joyce, Brad Crammond, Alan Carey
Methods: Objectives: explore how systems methodologies are being applied, identify areas of activity Design: SR of literature (representative but not comprehensive sample) Analysis: inductive qualitative content analysis (approach, methodology, transparency, strengths/weaknesses), data quality assessment, organization by theme
Results: Four categories of literature: (1) editorials, commentaries and reviews which called for the application of systems science (either broadly, or with regard to specific methodologies or to specific problems) to public health, (2) research which identified systems as a broad analytical lens applied to the research, but which did not draw on systems methodologies or specialist systems insights, (3) research that uses systems methodologies to benchmark best practice in a range of areas and (4) research that claims to have undertaken systems modelling (of different types and differing levels of rigour) Continuum of Systems Research: position pieces (outlining potential of systems science for public health), analytic lens (systems concepts for data analysis via general methods), benchmarking (systems methodologies to benchmark best practices), systems modeling (research to model real systems) Most promising: systems modeling, SS to benchmark best practice Benchmarking Examples: Johnston and Finegood39 used their systems leverage points framework, titled ‘intervention-level framework’, to discuss the potential benefits and limitations of public–private partnerships in addressing obesity and non-communicable diseases. MacLean et al42 provided a conceptual framework for vertical and horizontal connections to address childhood obesity. Using a Canadian case example, they were able to demonstrate the connections between different layers of government (vertical integration), and between sectors such as education and health (horizontal integration). It was commented that the model elucidated key partnerships across system elements, but a weakness in the model is that it does not account for dynamic system properties that could account for how and where change occurs in the system. Study by Sautkina et al via KII discovered limited understanding of SS approaches; conclusion that policy narative not very clear about what a "systems-based approach" meant and practitioners reverted to past experience SD Modeling in PH Guidance: model via 3rd party software should be available for download, implementation of model via open source or widely used software, model equations and variable relationships spelled out explicitly (see ref. 54), attempt made to validate results
The nature of public health means that social dynamic models will always be fluid, subjective and non-holonomic (ie, the model will depend on the process as much as the fundamental social conditions/data). However, this does not preclude accountability. For this area [benchmarking best practices] to be effective, research and implementation must go beyond assessing whether systems concepts are simply in use, and instead, consider the quality and effectiveness of systems-based practices and approaches. This requires greater research attention on the attributes of a systemlevel intervention and how it could be delivered and evaluated, in addition to the current focus on development of systems-thinking concepts Conceptualising systems in this way ["system as a metaphor"] allows the researcher to use notions in systems thinking, such as accumulation, feedback and endogenous behaviour as metaphors for facilitating knowledge transfer, thereby creating and/or revealing integration and comparison between the worldviews of system actors. This suggests that systems concepts can act as useful metaphors for enhancing our integrative practice, whether as health promotion practitioners or policymakers. Conclusion: much interest in application of systems concepts, soft systems modeling techniques may be most useful

18 - Guruprasad Madhavan, Charles E. Phelps, William B. Rouse, Rino Rappuoli
Methods: N/A
Results: N/A
The presence of numerous nongovernmental, private, and philanthropic participants as well as international partnerships, each with differing models for approaching population health issues, complicates integration, coordination, and consolidation in this system of systems. Complex human actions and behaviors emerge from many sources, including cultural patterns, economic forces (such as taxation), direct corporate marketing and advertising, and, in many cases, underlying genetic predispositions and also perhaps (social) media, all of which contribute their influences. Paper provides systems-level portrait of current and anticipated states of population health from systems engineering platforms; proposed architecture builds on complex systems architectures: Lvl 1 (Agents), Lvl 2 (Operations), Lvl 3 (Organization), Lvl 4 (Society) Benefits/Uses of Systems Architecture: modularity/flexibility, joint analysis of numerous data feeds Computational Models: Population, Socioecological, Epidemiologic, Risk and dispersion modeling, Multi-criteria analytics, Network analysis, Multi-agent modeling, Evolutionary programming Interlinked Programs: advanced simulation and forecasting, verification routines, graphical routines V6-D3-I3 Information Challenge (information needs) Feasibility of SA: SA for PH is feasible Managing SA: need new independent oversight and coordination, including budget authority (e.g., national health board similar to FAA, Federal Reserve) Dashboards: each federal agency, state agency, etc. to have different customized dashboard
19 - I. David Wheat
Methods: Survey of SD literature; exclusively within System Dynamics Review (SDR) The premise of this paper is that the public policy implementation literature can help SD modellers ask questions that improve the operational thinking required for designing model-based policy structure Our task is to think operationally about the process of policy design. We separate that process into two steps: (1) identifying strategic leverage points in the model through policy parameter testing, and (2) designing stock-and-flow structure that represents a particular policy tactic.
Results: System Dynamics Review (SDR) has published over 450 articles/notes with 1/3 addressing public policy issues; 51 cover model-based public policy analysis and 14 have models exhibiting new policy structures and decision rules begin by aggregating the SD modelling process into two high-level stages: Problem Explanation and Policy Design.4 The task in the first stage is to explain the reasons for the problematic dynamic behaviour of the system. That requires building and testing an explanatory model. In the second stage, the challenge is to design and test policies that alleviate the problem; that is improve the dynamic performance of the system. That requires building a policy structure (another 'model' if you will) that can be integrated with the explanatory model. For our purposes, the key term in Forrester's second-stage description is 'restructure'. At the policy-design stage, the explanatory model should be modified by adding stock-and-flow feedback structure that implements decision rules specifying when the new policy will become operational, how it will work, and what will happen over time to improve the performance of the system.6 And Sterman (2000, p. 104) emphasizes that 'policy design . . . includes the creation of entirely new . . . structures and decision rules'. Therefore, an SD model containing new policy structure has implementation ('how it would work') assumptions embedded in the policy design, at least implicitly. That does not mean the embedded assumptions are always valid. A goal-seeking pattern has some intuitive appeal as a generic description of how implementation might unfold. One might hypothesize that implementation proceeds rapidly at first but eventually saturates at a level reflecting constraints imposed by relevant legal, political, bureaucratic, and socioeconomic structures. On the other hand, S&M (1980, 1981) argue that the erosion pattern is more typical, at least with regard to regulatory policies. In their view, after a slow start, implementation gains momentum, only to run out of steam and erode after reaching a short-lived peak. Their argument also depends on the assumed effects of pertinent legal, political, bureaucratic and socioeconomic structures. In nonlinear feedback systems, model-based policies tend to have variable rather than constant impacts on dynamic problems. Thus, traditional static parameter sensitivity tests may not provide

sufficient insights about the potential impact of a policy strategy Moreover, S&M (1981) emphasize that those whose cooperation is needed to implement the policy must also subscribe to its underlying causal theory. By acknowledging the impediments to policy implementation and building them into the policy structure, the simulated behaviour is more likely to resemble the eventual real-world behaviour resulting from the policy. The value of the implementation framework is that it can be modified into a checklist of questions ('flags') useful to modellers seeking to represent implementation impediments in policy-design structure. When engaged in operational thinking at the policy-design stage, an analyst must make feasibility estimates. And Allison (1971) has argued that such estimates hinge on the analyst's mental model of how governments function in a particular policy context; that is the extent to which the analyst considers policy implementation (i) a choice by a rational unitary decision-maker, (ii) an output of bureaucratic organizational procedures, (iii) a result of political conflict and compromise, or some combination thereof. The mental model will influence the aggregation level in the policy structure of the SD computer model and, ultimately, the assessment of a policy's feasibility. Therefore, an SD modeller of public policy problems needs to develop an understanding of the relevant governmental policy structure in addition to the structure responsible for the historical dynamic problem. A checklist of implementation hurdles should emerge from comparing Allison (1971), Mazmanian and Sabatier (1981) and Hogwood and Gunn (1984). The checklist should be supplemented by considering policy instruments available to governments, as illustrated in Linder and Peters (1989) and Bardach (2005).
Limitations: focusing only on articles published in SDR may overlook those published elsewhere
20 - Jacqueline Merrill, Michael Caldwell, Maxine L. Rockoff, Kristine Gebbie, Kathleen M. Carley, Suzanne Bakken
Methods: NA within LHD (urban-suburban, 156 employees, 300k pop); survey (93% resp.); Quadratic Assignment Procedure (QAP) to determine correlation and standard error in network data; networks by 4Qs merged; binarized output (employee*task, employee*knowledge, employee*resources); collaborative analysis (researchers & staff); Measures: total degree centralization, characteristic path length, density, complexity, task redundancy, resource redundancy; Simulations: attrition by retirement, simulated merger of 2 divisions; Newman's modularity algorithm to explore subgroups in network (reflects degree of community structure with >3.0 being cohesive subgroups)
Results: QAP yielded high pairwise correlation coefficients (0.61-0.89) which may indicate PH may indicate expansiveness bias; nonlinear associations; total degree centralization (0.46 agency , 0.28-0.50 program) indicates "command and control" structure; characterisitc path length (2) suggests potential for rapid information diffusion; density (15% agency, 31-64% program) reflects less communication between than within programs; complexity (0.21 agency, 0.28-0.39 program) may indicate information silos; modularity of 0.31 (cohesive subgroups); attrition simulation (centralization doubled with removal of senior staff and halved with removal of supervisors); merger simulation (redundancies increased, density reduced, potential loss of influence for key employees); limited integration of environmental services
Nonlinear structure of associations between divisions contrasts with directed hierarchy of traditional org. chart; reduction in density with merger shown to aid network performance; findings afforded insights into organizational efficiency, strategic prioritization (cross-training & information distribution); low complexity high density may mean information silos (poor communication and duplicative) The findings from this study document that a local health department's network structure exhibits features common to other organizations. Local health department networks may also demonstrate common features that are shared across departments. If these features affect the functioning of each organization, this may have system-wide implications. The presence of a distinct environmental subgroup is an example; we found low integration of the environmental health services subgroup that may have a relationship to organizational effectiveness, efficiency, or performance. If this is a general feature of local health departments (which is consistent with informal observations by authors), then planning and resource management for the entire public health system could be affected.

The dynamics within organizations can obscure the determinants of performance because interactions among the multiple elements that comprise an organization are difficult to comprehend. For example, consider how difficult it has been for the public health practice community to measure performance across local health departments that vary in structure and composition due to local decisions. Yet, these departments have consistent missions and perform essentially similar work.
21 - Jessica G. Burke, Kristen Hassmiller Lich, Jennifer Watling Neal, Helen I. Meissner, Michael Yonas, Patricia L. Mabry
Methods: RE-AIM Framework: Reach: proportion and representation of participants vs population Effectiveness: success rate if implemented Adoption: proportion of people/settings/practices will adopt/participate in intervention Implementation: extent of intervention implemented as intended Maintenance: sustainment of program over time
Results: Case Study 1 (SD PRISM): Austin, TX utilized PRISM to support adoption of intervention program; PRISM can simulate and compare the reach of interventions under consideration, estimate effort required to implement and achieve goals, uncover unintended consequences Case Study 2 (ABM NetLogo): NetLogo simulated residents using the Theory of Reasoned Action (juveniles with probabilities of perpetrating crimes and adults with probabilities of witnessing/reporting crimes) Case Study 3 (NA PAS): examination of teacher advice networks implementing the PAS project by employing NA; NA may assist in understanding and improving network effectiveness and pinpoint key nodes (members or organizations)
SD: simulate interactions and changes of dynamic system ABM: ABMs specify decision rules (e.g., If-Then statements) and simulate agent interactions NA: examines structure of relationships between nodes, operationalized as discrete (e.g., does relationship exist?) or valued (e.g., how frequently does information flow?), between symetric (e.g., socializing) or directional (e.g., direction of advice)
22 - JM Bauer, PM Herder
Methods: Potential methods summarized by article: Constrained Optimization Approaches (in STS, nearly all decisions are constrained optimization problems): constraints from artifact features, decision-maker information constraints, limitations of decision-making process, STS layer constraints, and constraints from past choices; see section for optimization functions; recent contributions have modified the basic model for imperfect systems; challenge for design is to devise governance structures/processes that are incentive compatible; constrained optimization may not pay sufficient attention to the fundamental endogeneity of the workings of social systems System Approaches: cybernetics, structural functionalism, general systems theory, mathematic systems theory, system-of-systems (SoS have the following three traits that distinguish them from regular systems: (1) they are geographically distributed; (2) their overall functionality is primarily dependent on linkages between distributed systems; and (3) the systems are heterogeneous, especially because of the inclusion of sentient systems, such as thinking and evolving individuals or organizations) Complexity Theory: originated in physical and bilogical sciences and applied to social systems, only recently to governance and design of STS; complex STS can operate in different states (e.g., order, edge-of chaos, chaotic) and may be stable or may oscillate as phase transitions; agents connected via multiple flows over networks of nodes and connectors in which emergent behavior arises out of simple lower level system level behaviors and rules; complexity typically arises from social subsystems Overarching Objectives: In infrastructure industries, important overarching and specific goals are settled in a political and social discourse, typically by players with different information and power to influence the outcomes. Such “public values” reflect a “normative consensus about (a) the rights, benefits, and prerogatives to which citizens should and should not be entitled; (b) the obligations of citizens to society, the state, and one another; and (c) the principles on which governments and policies should be based” [Bozeman, 2007, p. 17]. Infrastructure industries, like other social and economic activities, abound with such opportunistic behavior of all private and public stakeholders (see [ten Heuvelhof et al., forthcoming] for a more extensive discussion).

Results: N/A
Infrastructure sectors can be considered as a particular class of socio-technical system [Kroes et al., 2006; Ottens et al., 2006]: technology is central for their operations and both organizational as well as sectoral forms of social control are established to ascertain a range of public values associated with their operation, such as ubiquitous and affordable supply. Engineering and social design issues arise at multiple levels of these socio-technical systems. Modern societies are heavily dependent on the services of multiple infrastructures (a term originally used by the military to refer to supporting transportation and logistical functions). Without reliable and sufficient supply of energy and water social and economic life would collapse quickly. Transportation and communication systems are required to coordinate the ever more differentiated tasks and the related flows of goods, services, and people that go hand in hand with increased specialization. The services of other infrastructure systems, such as sewerage, or waste removal, are similarly indispensable for a high quality of life and the overall well-being of society. The technical and social organization of infrastructure industries is strongly influenced by public values [Bozeman, 2007]. Worldwide, the traditional system built around strong government intervention and monopolistic industry organization has been superseded by market-based approaches in which government assumes regulatory rather than owner-operator functions. Infrastructure liberalization (the opening of market entry for new service providers) and sector unbundling (the separation of the stages of the value chain, for instance, electricity generation, transmission and distribution) have increased the number of participants and created multi-stakeholder environments. Layers & Time Scales in STS: At the lowest layer of the system, continuous decisions regarding resource allocation and operation are made. One layer up, the governance structure of a society (the "play of the game"), most importantly various contractual arrangements, is specified. Specific methods of regulation (e.g., cost-of-service versus price cap regulation), ownership decisions (e.g., state, private, or hybrid), and market design will be defined at this layer, ideally aligning governance structures with the nature of transactions. Markets, hierarchies, and networks are important forms of the broad range of available governance structures. Change at that level unfolds over periods of one to ten years. The next higher layer defines the institutional environment, the "formal rules of the game". Important design decisions at this layer encompass, among others, the organization of a polity, the organization of sector-specific regulation, and the general definition of property rights. Change on this layer is even slower than at the governance layer with some processes lasting up to a century. The space of theoretically possible design options ranges from one, for instance if a chemical process works only in one particular way, to many alternatives, for example, with regard to the topology of networks or the organization of the governance of infrastructure services. Due to the constraints imposed by the components of the socio-technical system on each other, only a subset of this theoretically possible space is within the realm of feasible choice options. From that space, specific choices are made that, taken together, constitute a specific configuration of socio-technical design choices. In the social domain, the combination of choices forms a particular institutional arrangement (or institutional design). In the technical domain one could refer to a specific technical arrangement (or artifact design). Taken together, social and technical design realizations form a highly differentiated and complicated socio-technical arrangement (socio-technical design) with corresponding unique performance characteristics. Comparative Assessment: The dominant constrained optimization approach tacitly assumes that socio-technical systems can be controlled and that sufficient solutions to a design problem can be found and implemented; would have been a reasonable simplification when infrastructure systems were organized as (state) monopolies - now replaced worldwide with a more open and competitive market environment The design of socio-technical systems is also strongly influenced by goals originating in political science and jurisprudence. The most important of these goals include constitutionality, legality, accountability, transparency, justice, equity, and universality of access. These goals have process-oriented aspects as well as substantive aspects. For example, constitutionality of an arrangement may imply that it corresponds to the substantive provisions of the respective constitution (e.g., with respect to the taking of private property in pursuit of public interest goals) or it may have procedural requirements (e.g., that a measure is formulated following constitutionally prescribed processes). Legal objectives are of particular importance for the design of the organizations entrusted with developing

specific policies for socio-technical systems (e.g., regulatory agencies, ministerial departments, competition authorities). Designing the overall legal and regulatory framework (the “order” or “constitution”) of a market and an entire economic sector is one of the most important design tasks confronted presently in socio-technical systems. The school of constitutional economics has devoted particular emphasis to these issues (see [Vanberg, 2005] for a succinct discussion of the position) although it tends to underestimate the role of the other components of the socio-technical arrangement.

23 - Julie M. Kapp, Eduardo J. Simoes, Anne DeBiasi, Steven J. Kravet

Methods: Baldridge framework as conceptual model for population health (sets direction, fact-based decision-making, incentive alignment, value).

Results: Baldridge application: Leadership Triad - Leadership (US DHHS), Strategic Planning (policy/legislation, ACA), Customer Focus (US pop.); Results Triad - Workforce Focus (WF1-National, WF2-State, WF3-Local), Operations Focus (strategy to attain results), Results; System Foundation - Measurement/Analysis/Knowledge Management (decentralized and uncoordinated vertically and horizontally, non-standardized, varied problem definition and lack of consensus).

Recommendation 1: drive a strategic outcome-oriented approach via national EBPH dashboard (align metrics, develop funding RFPs, develop dashboard). Recommendation 2: improve workforce operational effectiveness (RFPs require organizational profile).
Overall management framework integrating components into system perspective is missing (Baldridge Framework adaptation with two recommendations are sufficient).
Challenges: buy-in by HHS, resistance to alignment on strategy and core metrics between Levels, etc.

24 - Juliet Sims, Manal J. Aboelata

Methods: N/A

Results: N/A

The System of Prevention framework applies systems thinking to an analysis of successful prevention initiatives that achieved population-scale impacts, and outlines core, common elements of a successful system of prevention
The System of Prevention framework starts from the premise that we—as a society—designed the systems that shape our lives and determine our opportunities to be healthy, including the food, transportation, health care, and land use systems, to name a few. And that means we can redesign systems that predictably produce negative outcomes—like land use systems that locate toxic sites in communities of color, causing health issues like asthma, or food systems that incentivize the overproduction of junk foods and rely on the exploitation of low-wage workers—to produce health instead of illness, and to reduce rather than exacerbate inequities.
The framework also emphasizes the need to understand how systems interact with one another—how our immigration system interacts with our food system, for example, or how structural factors like racial injustice and economic inequality act across systems. Once we understand the ways systems have been designed and the roles they play in shaping the health of communities and populations as a whole, we can redesign systems
that currently produce illnesses, injuries, and inequities to foster health, safety, and equity instead (see Figure 1).
A System of Prevention brings together the systems and sectors that affect health in order to understand what elements need to be included in our public health infrastructure for it to be able to achieve health, safety well-being, and equity The system will look different
in each community, but there are some common elements and actions that a successful System of Prevention will include (see Figure 2).
Elements: shared vision, multi-level action, elevate community voices and leadership, facilitate community partnerships and multisector collaboration, empower a skilled prevention workforce (grounded in social justice), make the case for prevention and equity, gather and share data, generate stable sources of funding

25 - Kristen Hassmiller Lich, Jennifer Brown Urban, Leah Frerichs, Gaurav Dave

Methods: integrating: (1) GCM – an approach for broadly soliciting input on factors affecting a complex problem; and (2) SD – an approach to enrich understanding of how identified factors interconnect to shape system-level outcomes over time. We describe the use of GCM in strategic planning, and then illustrate how SD inquiry might extend GCM results.

Standard concept mapping methodology was employed (Kane & Trochim, 2007) including: (1) Preparation: generating the focus prompt, determining participants, and setting the project schedule; (2) Generation: brainstorming statements in response to the focus prompt; (3) Structuring: sorting statements for similarity, and rating statements on the dimensions of importance and feasibility; (4) Analysis: multivariate statistical analyses to represent ideas graphically through maps; (5) Interpretation: analysis of results in a facilitated session; and (6) Utilization: using results to address the intent of the project. 830 statements generated, then pared down to 97 unique statements; the 97 statements were provided to reviewers in addition to random statements from the original 830 in order to confirm the final set; structuring phase utilized a 5-point Likert scales for perceived importance (1-5) and feasibility (1-5) Structuring data were analyzed using Concept Systems Global MAX, resulting in a 5-cluster solution: Comprehensive and Coordinated Service Model, Life Skills, Personal Development, Positive Social Support and Connectedness, and Supportive Environmental Infrastructure While implementation of SD methods in practice is iterative, the general steps include: (1) defining the problem and system boundary; (2) creating an explicit (diagrammed) explanatory dynamic hypothesis about the system structure and causal linkages driving change in the system over time; (3) converting the qualitative dynamic hypothesis into a quantified simulation model, and testing the model against data and expert opinion; and finally, (4) using the model to facilitate learning about how the system behaves and how to impact it positively over time (Sterman, 2000). Strategic decisions are not typically made based on impact alone. With simulation results in hand the group might also engage in a discussion about the feasibility of alternate scenarios and how they may (or may not) leverage current strengths in the community. This enables a richer conversation about the relationship between resources required and improvement in outcomes across scenarios than is possible without quantitative impact estimates.
Results: Results are outcome of integrating GCM-SDM
group concept mapping (GCM) has been used to engage stakeholders to elucidate and synthesize factors shaping a wide range of systems problems and prioritize targets for action Causal Loop Diagramming (CLD) has been used to engage stakeholders to connect the complex cause-and-effect relationships influencing system outcomes in visual diagrams Systems science simulation modeling approaches, such as system dynamics (SD) or Agent-Based Modeling, have been used to quantify diagrammed relationships, inform evaluation targets, or compare intervention effects Practitioners are encouraged to embrace three thinking skills—"System as Cause Thinking, Operational Thinking, and Closed-Loop Thinking" (Richmond & Peterson, 2001). System as Cause Thinking pushes practitioners to identify system structure as the cause of problems rather than unchangeable factors imposed externally, perhaps requiring boundaries around investigation to be expanded. Operational Thinking drives us to describe the "plumbing" of systems in terms of stocks, flows, and other chains of variables determining change over time. Closed-Loop Thinking encourages us to identify the complex and often reciprocal interactions between influential variables, which lead to vicious/virtuous cycles (when an earlier change is reinforced within a system) or balancing forces (when the system counteracts change), and to evaluate or strategize with this feedback structure in mind. Together, this approach to systems thinking facilitates the development of solutions that are framed in this richer under-standing of the sources of system behavior (e.g., limits to change, forces that seek to undermine or drive change for better and worse).
26 - M Schwaninger, S Ulli-Beer…
Methods: SDM for decision-making Research Questions: what are factors triggering behavior? How can actor behavior be influenced? The research strategy chosen is one of action science. Argyris et al. (1985) define action science as a research approach that combines the study of practical problems with research that contributes to theory building and testing Phases: problem structuring and conceptualization, development of dynamic theory Phase 1 - Problem Structuring and Conceptualization: literature review, 3 group model building

workshops Phase 2 - Developing a Dynamic Theory: model building, testing, design, updating
Results: N/A
Recommendations: design for transdisciplinary inquiry, use frameworks to manage relevant body of knowledge, apply unifying perspective when structuring issues, choose proper methodology for dynamically complex issues, customize the policy mix, master the crux of policy implementation and policy resistance, utilize participative research design,
27 - Marta Lenartowicz
Methods: This thesis, derived from a basic property of open systems (Bertalanffy 2009), i.e., systems whose functioning is based on a constant two-way exchange of information and resources with their environment, attained its greatest maturity and popularity in management science after 1966 when it was applied to human organizations by Daniel Katz and Robert L. Kahn (1966).
Results: N/A
It was only after the seminal contribution of Katz and Kahn that the "mainstream" management science focused on interactions between organizations and their environments and started to consider the boundaries of the organization as an exceptionally rich locus of potential for engendering organizational change If external change brings in its wake internal change, an intentional orchestration of the external stimuli affecting the organization may be just as potent in producing internal changes as the social, cultural political, economic, and technological influences which arise and spontaneously shape organizations Contemporary organization subsystems: goals/values, psychosocial, technical, structural, management; management (working through boundaries) and psychosocial (over and above boundaries) have carrying capacity for propagating/reinforcing change The autonomy of an autopoietic system results from two of its properties: first, the continued existence of such a system depends above all on its own activity; second, it is the system itself that defines its own boundaries (Mingers 1995: 37). This leads to a new—operational—view of the boundaries of a living system; the boundary is located wherever the repeating, circular, self-referential activity that continuously rebuilds the system ends Operational Closure: every possible activity of the system leads to further activity of the system (predefined by the specific organization of their own autopoietic systems) External Stimuli (compensatory reactions): if not activating patterns, ignored; if cannot be ignored, perturbation which may lead to system disintegration Organizations as abstract autopoietic systems At best, these external influences can become perturbations, but they cannot direct the organization's reaction to the perturbations according to the policy-makers' desires. This theoretical incommensurability gives rise to a practical problem: from the viewpoint of the early systems approach, while the implementation of strategic public policies through the external induction of organizational change seems possible, rational, and effective, from an approach that conceptualizes organizations as autopoietic systems, serious doubts may be raised as to whether implementation of strategic public policies may indeed occur. The perspective on organizations as autopoietic systems puts into question the currently dominating, evidence-based approach to monitoring and evaluating strategic policy implementation, both of which rely on successful induction of organizational changes. one might conclude that when the external steering of change within autonomous organizations is evaluated on the basis of the measurable outputs produced by such systems, the evaluation's results should be assumed to be gravely misleading. This is a general weakness of the evidence-based public policies, which derive their evidence from inductive and quantitative socioeconomic models. The reputation of such models especially suffered during the 2007 financial crisis, which, according to Nassim N. Taleb (2007), was caused exactly by too much trust being continually placed in the models. The common contemporary approach to governance dictates that the organizational changes required to implement a public strategy, if not inducible through regulation, can be best provoked by financial stimuli.
28 - Mary E. Northridge, Sara S. Metcalf
Methods: N/A

Results: N/A
A complex (adaptive) system has been usefully defined as a system comprised of a large number of entities that display a high level of interactivity that is largely nonlinear containing demonstrable feedback loops There are a number of other basic observations that have been made through the examination of complex systems, primarily through the use of computer simulation and the mathematics of nonlinearity, including selforganisation meaning insensitive to large disturbances and incompressibility, meaning any reduction in complexity will result in the loss of system aspects. The overarching point is that rather than focusing on the parts of a system and how they function, one must focus on the interactions between these parts, and how these relationships determine the identity not only of the parts, but of the whole system Implementation is dependent upon a complex framework of sanctions and incentives reinforced by monitoring and adjustment Conclusions: model the problem, not the system (conduct formative research with collaborative models); pay attention to what is important, not just what is quantifiable (use qualitative data to derive causal relationships); leverage the utility of models as boundary objects (create modifiable and readily perceptible representations of models); adopt a portfolio approach to model building (work in parallel to develop separate but related models)
29 - Navid Ghaffarzadegan, John Lyneis, George P. Richardson
Methods: URBAN1 Scenario (exogenous increase in regional jobs) Swamping Insight (TANF family system); sensitifity analysis performed for changes in capacity at upstream and downstream and plot final equilibrium stage vs changes in capacity
Results: URBAN1 model (jobs creation): feedback undermines policies via policy resistance; B3 - exogenous increase in jobs decreases ratio of labor-to-jobs, raising attractiveness of region, increasing population, overwhelming jobs; B5 - increase in jobs decreases pressure to expand business, declines jobs, undermining gains to unemployment URBAN1 modification (B3 and B5 inactive): policy achieves intended result of reduction in unemployment (newly created jobs immediately taken) Swamping Insight sensitivity analysis: increase in downstream capacity leads to system improvement whereas increase in upstream capacity without downstream can overload system and lead to system decay
Small SD models: few significant stocks and 7-8 major feedback loops Article reviews 5 characteristics of public policy problems: policy resistance, need for experimentation and cost of experimentation, need to achieve consensus between diverse stakeholders, overconfidence, and need to have an endogenous perspective Policy Resistance: complexity of environment leads to policy resistance, feedback which undermines policy and may exacerbate original problem; common in systems with many or strong balancing feedback loops and delays between policy and action. These examples illustrate how attempts to intervene in complex systems often fail when policymakers fail to account for important sources of compensating feedback from the environment. Traditional tools that lack a feedback approach may therefore fail to anticipate the best policy actions. Experimentation: experiential learning (e.g., piloting) may be beneficial for effective policy-making; systems are not easily reversible and ineffective policy may lead to worse behavior Consensus Among Stakeholders: decision-making involves multiple stakeholder groups for implementation Policymaker Overconfidence: common among both naive and expert decision-makers; overconfidence common for moderate or extremely difficult questions or when regarding own capabilities; may lead to inaccurate decisions and difficulties working with stakeholders Endogenous Perspective ("self-serving bias" or "misperception of feedback"): tendency to attribute undesirable events to exogenous rather than endogenous sources (e.g., attributing shortfalls of policies to oppositional parties); endogenous perspective necessary for individual and organizational learning Simplified Forrester's Urban Dynamics model (URBAN1): goal to understand causes of urban decay, evaluate existing policy responses, and generate discussion on approach (highly controversial); disaggregated and contains 9 major stock variables (3 sector-specific stock variables in causal structure); two reinforcing loops dominate and create exponential growth in housing, business, and

population; two feedback loops support job availability and housing availability; growth leads to land scarcity (dominance shifts from R1-R2 to B1-B2), housing and business growth further contributes but space limitations outweigh increases to regional attractiveness, population/housing/business overshoots, excess housing (preference over business structures) leads to decay (attracts population beyond that supported by business opportunities), final equilibrium in which standard of living declines enough to stop population growth; central insight is that total attractiveness of an urban region must be considered relative to surrounding regions - policies that increase both business and housing are most effective (e.g., adding a zoning system); second insight is that decay arises from natural asymmetries between business and housing Swamping Insight Model (NY welfare policy): goal of examining effect of investment in different parts of system (developed by group model-building) as a common archetype of systems with recidivism (effect of increasing upstream capacity); model uses aging chain structure to represent flow of TANF recipients with two main stock variables for total at-risk population (TANF Families, Post-TANF Employed) and two supportive capacity variables (TANF Support Capacity, Post-TANF Support Capacity); number of TANF Families increases upon entry to program and decreases upon employment (Post-TANF Employed), Post-TANF Employed become TANF Families upon job loss, TANF Support Capacity influences Job Finding Rate (facilitates becoming Post-TANF Employed), Post-TANF Employment Support Capacity influences Probability of Recidivism (facilitates reduction of risk); The final equilibrium level of at-risk families is an important concern for policymakers and this model is able to show how various investments infl uence that level. Swamping Insight model aims to 1) develop holistic view of problem, 2) better understand counterintuitive findings, 3) experiment for key policy options, and 4) learn about swamping insight and endogenous causes of policy failure 4 critical small system dynamics models characteristics: feedback approach and emphasis on endogenous explanations of behavior, aggregate approach, simulation approach, and small size of model (clear structure and link to behavior) Feedback Approach: emphasizes endogenous sources of behavior from within system (and may be perceived as counterintuitive), counterintuitive behavior often policy resistance (unanticipated compensating feedback) Aggregate Approach: models groups of individuals and neglect more detailed implications from agent heterogeneity, differential equation-based models (such as these) are easier to understand and have similar policy implications, aggregation reduces the size of the model as well as the cost to experiment, focuses on stocks and flows of building structure (assists in understanding accumulation dynamics) Simulation Approach: allows for substantial insight and illustrate why rational policies may lead to policy resistance, allows for experimentation without substantial cost or investment, allows for consensus-building and discussion Small Size: allows for exhaustive experimentation through parameter changes, easier to perform sensitivity analysis and examine interactions between parameters, allows for easier understanding and holistic view Limitations: small models unable to meet demand for comprehensive model that considers all causal links (policymakers may lose trust if a key or hypothesized link is not present), lack of inclusion of specific agents may decrease trust in model (or increase likelihood that stakeholders require model increase their agents inclusion), may lead modelers to underestimate role of critically important feedback loops, models should not impede "operational thinking" and modeling
30 - Nicholas P. Patorniti, Nicholas J. Stevens, Paul M. Salmon
Methods: This paper is exploratory in nature and scene setting for future research into the application of STS methods and city design. The paper presents a viewpoint into the compatibility of STS approaches and city design. No qualitative or quantitative data gathering and analysis was undertaken. In this regard, this paper lacks a practical ‘proven’ approach as it is the first step to establish a context for future practical application. The aim of this study is to explore if cities can be viewed as complex sociotechnical systems (STS) and whether or not city design is compatible with STS approaches. It does this by assessing city characteristics against the theoretical characteristics of systems complexity and STS. We then utilised the case study of a ‘main street’ to explore the compatibility of STS theory content principles to city design. Here, STS refers to human factors and ergonomic related theories and methods as opposed to other

study areas like science technology (society) studies whereby STS has a different meaning. STS in the science technology studies context relates to concepts like social construction of technology (Pinch & Bijker, 1984) and its subtopics including actor-network theory (Latour, 1996). STS theory and methods have been identified as providing appropriate frameworks to consider complex urban environments and their design and planning in Stevens (2016); and Stevens and Salmon (2014; 2015). These previous papers, however, do not explore the applicability of cities against the characteristics of complexity and STS nor do they explore the compatibility of STS theory content principles to city design.We set out to establish this connection, as a prequel to further applying STS methods in city design.
Results: The existence of two characteristics of complexity and two characteristics of sociotechnical systems were used to provide evidence of complexity and sociotechnical systems. Other characteristics do exist and cities are considered by the authors to have evidence of these. However, given the nature of this exploratory paper, two characteristics for each are documented and considered sufficient evidence to meet the aims of this paper. For complexity, other characteristics are detailed in Cilliers (1998) and other characteristics of STS are detailed in Clegg (2000). A city is not a closed system as these open system environments involve inputs from other sources not directly contained in the city. Similar to STS approaches, city design seeks to understand and manage both aspects. When city design constructs urban environments (technology) the comfort and wellbeing of people (socio) is maximised. Walker et al. (2008) summarises that sociotechnical 'theory' as all about 'joint optimisation'. Optimisation of the parts of the system independently or in isolation, tends to increase not only the quantity of unpredictable, 'un-designed', non-linear relationships, but those relationships that are actually injurious to the system's performance (Walker et al., 2008). Interchange and integration between main street functions should be able to occur as seamlessly as possible. Also consider the boundaries between public and private space or boundaries between zone restrictions from regulatory boundaries associated with the local planning scheme. Boundaries in a main street context are managed by people, governance and technology. This includes management by: people via human intervention (casual surveillance managing opportunities for crime); governance via local planning scheme, local laws, government design guidelines and; management by technology via barriers. The main street design is specific to the key functions and is a context sensitive solution rather than an imported or copied solution which is less appropriate. For each of the main street functions, sufficient information is required to complete each task. At key intersections, nodes and decision making points within the main street, information is provided considering access to amenities, where to park and meet, opening times, dining options, pedestrian crossing and commercial signage. To ensure appropriate access to the main street, users need equitable authority and responsibility regarding its design and ongoing operation Systems are congruent when main street functions are compatible, tasks are in harmony and users do not perceive a conflict. Suboptimal development of cities is occurring worldwide due to the complex nature of these urban environments. Whole of system STS approaches to city design offer an advanced understanding of the complexities inherent in cities. This advanced understanding has the ability to optimise city design to successfully accommodate the urbanising world population through the more efficient use of urban land. Understanding how, what and why a city works, across traditional disciplinary and spatial silos, from a whole of systems perspective, has the ability to provide a higher level of city understanding for optimal development.
While the processes of urban renewal are critical to the success of our cities, they are complex undertakings as urban planners and local decision makers' deal with multifaceted assessments and trade-offs (Witlox, 2005). Within these developed areas there is an array of government, community and business stakeholders all involved in the allocation and existing use of land Adding to complexity, the design of these spaces represents a concentration of multidisciplinary perspectives. These often include urban planners and designers, engineers, architects and importantly also the disciplines of community development, social planning, social infrastructure, economists and

property investments. Systems approaches on the other hand, provide a broader consideration of the factors across disciplinary and spatial silos as well as how the development fits within the overall city system. It does this by looking at the inhibiting or affordance factors across all aspects of the city system. In addition, it considers a city design according to the complete system in context of overall purposes, processes, functions and tasks. This is a significant advancement to approaches which fail to contemplate interrelations across the whole system. This STS based approach offers to treat all aspects as relevant, consolidating strengths and weaknesses of the system, balanced across discipline design silos, stakeholders, city purposes and functions. An STS approach to city design offers decision-makers clearer insights into what design changes may assist this complex environment and possibly optimise the design functions and planning policy. Such knowledge may allow the city to be adaptable in the face of disturbances arising from the external environments and influence. This is especially important in the modern age of technologically complex, distributed, high-risk domains for which reductionist approaches with assumptions of linearity and rationality are no longer appropriate
31 - Philip Haynes
Methods: N/A
Results: N/A
New Public Managerialism/Management (NPM) shifts toward de-politicisation of administrators but relies upon an assumption of a high degree of system predictability and control, managing economy of inputs, efficiency of inputs to outputs, and effectiveness of outputs to generate outcomes; complex system approaches criticize this and assert that public managers work in unpredictable systems contingent on the external environment which overlap with public and private systems, and allow for bottom-up creativity and resistance A complex system has many cases (e.g., people and organizations) and elements (e.g., places and processes) with many dynamic interactions (reinforcing/balancing feedback) between them with [bounded rationality] and limitations in response. Levels of Public Policy: macro (national/continental), meso (local/organizational), and micro (individual) Complex systems regarded as open, without permanent boundaries, overlapping with other systems/subsystems. Inability to share information equally is common; dynamic flows of energy are episodic and nonlinear Attractor: mechanism that defines periods of relative stability; in mathematics, attractors define boundaries of system change and create definition of patterns and shape of system order; in social/organizational systems, stability and order can be provided by rules or values Stone's Cluster Components of Public Management Values: collective public ethos of public protection (i.e., preservation of public good); requirement to value efficient use of resources; public managers expected to deliver equitable services; public managers need to balance the public good with the liberty and dignity of the individual Policy systems have many cases (e.g., policy actors and organizations)
32 - Robin C. Purshouse, Alan Brennan, John Holmes, Petra S. Meier
Methods: N/A
Results: N/A
N/A
33 - WM Trochim, DA Cabrera, B Milstein, RS Gallagher, SJ Leischow
Methods: we conducted an initial study with systems thinkers (individuals involved in ISIS and the Syndemics Prevention Network) in which we used a systems methodology—structured concept mapping—to describe the challenges of systems thinking and modeling in public health. Participants: Syndemics Prevention Network (>300 from 11 countries), ISIS (60 from CA, AU, US) Concept Mapping (web-based): brainstorming according to agreed-upon focus statement (practical challenges to use of systems thinking/modeling in PH); synthesis and editing of statements to final set; participant sorting statements into groups and ranking priority; assessment by multivariate statistical analyses with multidimensional scaling and hierarchal cluster analysis

Limitations: limited engagement with cross-section of participants (ameliorated via independent replications and studies involving the use of alternative methods for challenge identification)
Results: Brainstorming (133 participants): 318 statements generated Synthesis to Final Set: 100 final statements used Sorting (56 participants), Rating (54 participants) Concept Maps (stress value of 0.300): similar statements located near one another in 8 clusters: Expand Cross-Category Funding, Support Dynamic and Diverse Networks, Use Systems Measures and Models, Inspire Integrative Learning, Explore Systems Paradigms and Perspectives, Show Potential of Systems Approaches, Foster Systems Planning and Evaluation, Utilize System Incentives
We offer 2 organizing ideas (dynamics and complexity), 2 influential metaphors (mechanical and biological) that can help us understand this daunting array, and 2 misconceptions. Dynamics: changes related to 1) settling into state of equilibrium, 2) changes in repeating cycles, or 3) changes in more complicated ways; Complexity: systems consisting of many interacting parts that must continuously adapt, often having emergent (unpredictable) behavior and autonomous agents self-organizing by simple rules; Complexity Theory is the study of complex adaptive systems Mechanical Systems: systems construed as machines made up of parts or subsystems that interact in complex ways to produce characteristic behaviors Biological Systems: systems are living and evolving entities and often comprised of subsystems that evolve and adapt to environment Misconceptions: systems thinking is not a rejection of traditional scientific views (linear, reductionist, mechanistic, atomistic, framed by mechanical/spatial/temporal metaphors); systems thinking does not lack scientific rigor (systems thinking includes both 'soft' and 'hard' techniques) Resultant Cluster Concept Map: clusters may be thought of as dynamically interacting conceptual/thematic agents influencing other clusters when coupled as each cluster resembles a semi-autonomous agent functioning in highly integrated system; map may be viewed via theory of complex adaptive systems in which simple local rules lead to emergent complexity The especially intriguing hypothesis from a systems point of view is that if multiple independent agents (individuals and organizations) follow the 8 rules represented by the cluster names and are provided with appropriate feedback about what is occurring as a result, systems-oriented organizations and networks will naturally emerge in the public health system. Project is significant because: 1) concept map provides basis for subsequent action, 2) results clearly point to need for education/learning in systems science, 3) map provides conceptual model for developing role play simulations, 4) concept mapping helps establish appropriate and widely shared boundary for thinking of issues
34 - Y Bar-Yam
Methods: N/A
Results: A fundamental result of multiscale analysis is that for a particular set of components, the area under the C(k) curve is independent of organizational structure… The organizational structure therefore selects a trade-off in capability at different scales (i.e., org. that responds at large scale may not respond at fine scale)...=> Different industries should be organized in different ways. Heterogeneous organizations: less restricted by form, supports task separation, allow individually appropriate and complex roles Degree of separation ("Spectrum") and specific services to be separated to be explored (could place population-level with front-line and may be public or private); separating large-scale prevention/population-based care frees physicians for individualized/complex care. Separation evokes concerns about reciprocal communication.
Multiscale analysis & complexity profile can characterize the function and desirability of organizational forms. Multiscale analysis (generalization of statistical analysis with k-fold correlation) and complexity profile capture relationship between set of possible behaviors with interdependencies-communication channels. Multiscale analysis determines how many components in system are coupled (engaged in same activity). Multiscale analysis suggests that a key to organizational effectiveness is the matching of the scale of processes to the task. Public health systems with public and private organizations effective at large-scale prevention and population care more effective long-term (do not require decision-making on individual basis). Recommendation for individuals to carry portable PHI.

Economy of scale to make certain screenings cost-effective.
Key concepts: limitations in centralized control of complex care, constructive role and limitations in automation, critical analysis of structures/flows to identify errors/inefficiencies, and understanding how to induce organizational change and improvement

Appendix E – Full List of Articles Included in Scoping Review

1. Bar-Yam Y. Improving the effectiveness of health care and public health: a multiscale complex systems analysis. Am J Public Health. 2006;96(3):459-466.
2. Bauer JMH, Paulien M. Designing Socio-Technical Systems. In: Meijers AG, Dov M.; Thagard, Paul; Woods, John;, ed. Handbook of the Philosophy of Science. Volume 9: Philosophy of Technology and Engineering Sciences. Elsevier BV; 2009.
3. Bozeman B. What Organization Theorists and Public Policy Researchers Can Learn from One Another: Publicness Theory as a Case-in-Point. Organization Studies. 2013;34(2):169-188.
4. Burke JG, Lich KH, Neal JW, Meissner HI, Yonas M, Mabry PL. Enhancing dissemination and implementation research using systems science methods. Int J Behav Med. 2015;22(3):283-291.
5. Carey G, Malbon E, Carey N, Joyce A, Crammond B, Carey A. Systems science and systems thinking for public health: a systematic review of the field. BMJ Open. 2015;5(12):e009002.
6. Dawoody A. "The Nexus" as a Complexity Model for Public Policy. Paper presented at: The International Multi-Conference on Complexity, Informatics and Cybernetics: IMCIC 20102010; Orlando, FL, USA.
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Appendix F – Descriptions of Key Variables

Table 20. Latent Categorical Variables

Variable Description	Label or Name	Response Items
LHD governance categorization	“governance” (labeled ‘c0govcat’ by NACCHO)	‘unit of state government’ ‘unit of local government’ ‘unit governed by both state and local authorities’
LHD jurisdiction classification	“centrality” (labeled ‘c0jurisdiction’ by NACCHO)	‘city’ ‘county’ ‘city-county’ ‘multi-city’ ‘multi-county;’
LHD was part of a combined health and human services agency	“colocation” (designated ‘c2q501’ by NACCHO)	‘Yes’ 'No’ ‘Do not know’
LHD had services or resources sharing arrangements with other LHDs	“integration” (designated as matrix variable ‘m8q*^’ by NACCHO, with * = 401/402/403/601/602 and ^ = a/b/c)	‘shared [functions]’ ‘[formal] agreement’ ‘informal [agreement]’ ‘none’

Table 21. Service Delivery Categories and Sharing Suffixes (*2016 & 2019 study years*)

Services Labels	Core QID*	Unique Label	Type
Business (community-based)	m13q281	Business	Private
Colleges or universities	m13q280	Academia	Government
Community health centers	m13q265	CHC	Medical
Community-based nonprofits	m13q286	CBO	Private
Cooperative extensions	m13q274	Res. Exch.	Government
Criminal justice system	m13q284	Justice	Government
Economic and community development agencies	m13q270	Development	Government
Emergency responders	m13q268	Responder	Medical
Faith communities	m13q278	Faith	Social
Health insurers	m13q267	Insurer	Private
Hospitals	m13q263	Hospital	Medical
Housing agencies	m13q271	Housing	Social
K–12 schools	m13q275	K12	Government
Libraries	m13q279	Library	Government
Local planning agency	m13q269	Planning	Government
Media	m13q282	Media	Private
Mental health/Substance abuse providers	m13q288	SAMHS	Social
Parks and recreations	m13q276	ParkRec	Government
Physician practices/Medical groups	m13q264	Physician	Medical

Services Labels	Core QID*	Unique Label	Type
Transportation	m13q277	Transport	Social
Tribal gov't agencies	m13q283	Tribal	Government
Veterinarians	m13q289	Vets	Private
*** NACCHO core QID is paired with a suffix**: *Shared Personnel/Resources* (a), *Written agreement* (b), *Regularly scheduled meetings* (c), *Exchange information* (d), *No relationship* (e), or *N/A* (f)			

Table 22. Service Delivery Categories and Sharing Suffixes (2016 & 2019 study years)

Services Labels	Core QID*	2016	2019	Label	Type	Class	Subclass	Program
Adult Immunizations	c6q55	X	X	IMM	Delivery	Pop	FA	Communicable
Air Pollution	c6q127	X	X	AirP	Policy	Pop	FA	Air-Water-Waste
Animal Control	c6q131	X	X	AC	Delivery	Ind	Ind	Other EPH
Asthma Prevention	c6q138	X		AP	Policy	Pop	FA	Air-Water-Waste
Behavioral Risk Factors	c6q83	X	X	BRFSS	Surveillance	Pop	FA	Chronic
Behavioral/Mental Health Services	c6q78	X	X	BHMH	Delivery	Ind	Ind	Behavioral
Blood Lead	c6q64	X		BL	Screenings	Pop	FA	Chronic
BMI	c6q142	X	X	BMI	Screenings	Pop	FA	Chronic
Body Art Vendors	c6q105	X	X	BAV	Regulatory	Pop	FA	Business
Campground / RV Vendors	c6q97	X	X	CRV	Regulatory	Pop	FA	Home-Lodging
Cancer	c6q60	X	X	Can	Screenings	Pop	FA	Chronic
Cardiovascular Disease	c6q61	X	X	CVD	Screenings	Pop	FA	Chronic
Childhood Immunizations	c6q56	X	X	IMM	Delivery	Pop	FA	Communicable
Children's Camps	c6q103	X	X	Camp	Regulatory	Pop	FA	Home-Lodging
Chronic Disease Prevention	c6q89	X	X	CDP	Prevention	Pop	FA	Chronic
Chronic Disease Surveillance	c6q81	X	X	CDS	Surveillance	Pop	FA	Chronic
Communicable/Infectious Disease	c6q80	X	X	CDz	Surveillance	Pop	FA	Communicable
Comprehensive Primary Care	c6q75	X	X	PC	Delivery	Ind	Ind	Medical
Correctional Health	c6q139	X		CH	Delivery	Ind	Ind	Medical
Cosmetology Businesses	c6q104			CB	Regulatory	Pop	FA	Business
Diabetes	c6q62	X	X	Dia	Screenings	Pop	FA	Chronic
Emergency Medical Services	c6q130	X	X	EMS	Delivery	Ind	Ind	Medical
Environmental Health	c6q84	X	X	EH	Surveillance	Pop	FA	Other EPH
EPSDT	c6q73	X	X	EPSDT	Delivery	Pop	FA	MCH-Social
Family Planning	c6q68	X		FP	Delivery	Ind	Ind	Medical
Food Processing Vendors	c6q110	X	X	FPV	Regulatory	Pop	FA	Business
Food Safety Education	c6q118	X	X	FSafe	Delivery	Pop	FA	Business
Food Service Establishments	c6q114	X	X	FServ	Regulatory	Pop	FA	Business

Services Labels	Core QID*	2016	2019	Label	Type	Class	Subclass	Program
Groundwater Protection	c6q122	X		GWP	Delivery	Pop	FA	Air-Water-Waste
Hazardous Waste Disposal	c6q125	X		HWD	Delivery	Ind	Ind	Other EPH
Hazmat Response	c6q124	X	X	Haz	Delivery	Pop	FC	Other EPH
Health-Related Facilities	c6q115	X	X	HRF	Regulatory	Pop	FA	Medical
High Blood Pressure	c6q63	X	X	HBP	Screenings	Pop	FA	Chronic
HIV/AIDS Screenings	c6q57	X	X	HIVS	Screenings	Pop	FA	Communicable
HIV/AIDS Treatment	c6q65	X	X	HIVT	Delivery	Pop	FA	Communicable
Home Health Care	c6q76	X	X	Home	Delivery	Ind	Ind	Medical
Hotels/Motels	c6q101	X	X	HotMot	Regulatory	Pop	FA	Home-Lodging
Housing	c6q116	X	X	House	Regulatory	Pop	FA	Home-Lodging
Indoor Air Quality	c6q117	X	X	IAQ	Policy	Pop	FA	Air-Water-Waste
Injury Prevention	c6q87	X	X	InjP	Prevention	Pop	FA	Injury
Injury Surveillance	c6q82	X	X	InjS	Surveillance	Pop	FA	Injury
Insurance Navigation	c6q135	X		InsN	Delivery	Ind	Ind	Medical
Laboratory Services	c6q134	X	X	Lab	Delivery	Pop	FC	Other
Land Use Planning	c6q121	X	X	LUP	Policy	Pop	FA	Other EPH
Maternal and Child Health	c6q86	X	X	MCH	Surveillance	Pop	FA	MCH-Social
MCH Home Visits	c6q72	X		MIECHV	Delivery	Ind	Ind	MCH-Social
Medical Examiner's Office	c6q141			ME	Delivery	Ind	Ind	Medical
Mental Illness	c6q95	X	X	MI	Prevention	Pop	FA	Behavioral
Milk Processors	c6q111	X	X	Milk	Regulatory	Pop	FA	Business
Mobile Homes	c6q96	X		MobH	Regulatory	Pop	FA	Home-Lodging
Noise Pollution	c6q128	X	X	NP	Policy	Pop	FA	Other EPH
Nutrition	c6q90	X	X	Nut	Prevention	Pop	FA	Chronic
Obstetrical Care	c6q70	X		ObsC	Delivery	Ind	Ind	Medical
Occupational Safety and Health	c6q132	X		OSH	Delivery	Ind	Ind	Other
Opioids Abuse	c6q145		X	SA	Prevention	Pop	FA	Behavioral
Oral Health	c6q77	X	X	OH	Delivery	Ind	Ind	Medical
Other Pollution	c6q126			OP	Policy	Pop	FA	Other EPH
Other STD Screenings	c6q58	X	X	STDS	Screenings	Pop	FA	Communicable

Services Labels	Core QID*	2016	2019	Label	Type	Class	Subclass	Program
Other STD Treatment	c6q66	X	X	STDT	Delivery	Pop	FA	Communicable
Other Substance Abuse	c6q146		X	SA	Prevention	Pop	FA	Behavioral
Pharmaceutical Disposal	c6q129	X		PD	Delivery	Ind	Ind	Medical
Physical Activity	c6q91	X	X	PA	Prevention	Pop	FA	Chronic
Prenatal Care	c6q69	X	X	PnC	Delivery	Ind	Ind	Medical
Private Drinking Water	c6q113	X	X	PriDW	Regulatory	Pop	FA	Air-Water-Waste
Property Lead	c6q109	X	X	PL	Regulatory	Pop	FA	Other EPH
Public Drinking Water	c6q112	X	X	PubDW	Regulatory	Pop	FA	Air-Water-Waste
Public Health Nuisance Abatement	c6q144	X	X	PHNA	Delivery	Pop	FA	Other EPH
Radiation Control	c6q119	X	X	RC	Policy	Pop	FA	Other EPH
Recreational Water	c6q143	X	X	RW	Regulatory	Pop	FA	Air-Water-Waste
School Health	c6q137	X	X	SH	Delivery	Ind	Ind	Medical
School-Based Clinics	c6q136	X	X	SBC	Delivery	Ind	Ind	Medical
Schools/Daycares	c6q102	X	X	SchDay	Regulatory	Pop	FA	Business
Septic Systems	c6q100	X	X	SS	Regulatory	Pop	FA	Air-Water-Waste
Smoke-Free Ordinances	c6q108	X		SFO	Policy	Pop	FA	Air-Water-Waste
Solid Waste Disposal Sites	c6q98	X		SWDS	Regulatory	Pop	FA	Air-Water-Waste
Solid Waste Haulers	c6q99	X		SWH	Regulatory	Pop	FA	Air-Water-Waste
Substance Abuse	c6q94	X		SA	Prevention	Pop	FA	Behavioral
Substance Abuse Services	c6q79	X	X	SAS	Delivery	Ind	Ind	Behavioral
Surface Water Protection	c6q123	X		SWP	Delivery	Pop	FA	Air-Water-Waste
Swimming Pools	c6q106			RW	Regulatory	Pop	FA	Air-Water-Waste
Syndromic Surveillance	c6q85	X	X	Syn	Surveillance	Pop	FC	Other
Tobacco Retailers	c6q107	X	X	TR	Regulatory	Pop	FA	Business
Tobacco Use	c6q93	X	X	TBU	Prevention	Pop	FA	Behavioral
Tuberculosis Screenings	c6q59	X	X	TBS	Screenings	Pop	FA	Communicable
Tuberculosis Treatment	c6q67	X	X	TBT	Delivery	Pop	FA	Communicable
Unintended Pregnancy	c6q88	X		UP	Prevention	Pop	FA	MCH-Social
Vector Control	c6q120	X	X	VC	Policy	Pop	FA	Other EPH
Veterinary Public Health	c6q133			Vet	Delivery	Ind	Ind	Medical

Services Labels	Core QID*	2016	2019	Label	Type	Class	Subclass	Program
Violence	c6q92	X		Vio	Prevention	Pop	FA	Injury
Vital Records	c6q140	X		Vit	Delivery	Pop	FC	Other
Well-Child Clinic	c6q74	X	X	WCC	Delivery	Ind	Ind	Medical
WIC	c6q71	X	X	WIC	Delivery	Ind	Ind	MCH-Social
*** NACCHO core QID is paired with a suffix**: *Performed by LHD Directly* (a), *Contracted Out by LHD* (b), *Provided by Others in Community Independent of LHD Funding* (i), *Not Available in Community* (f), *Don't Know* (g)								

Table 23.County Health Rankings & Roadmaps Measure Information

Measure	Missing Counties (*out of 3142*)	Minimum	Maximum	Mean of Counties	Standard Deviation	10th Percentile	Median	90th Percentile	US Overall
Premature death	61	2,600	35,100	8,500	2,700	5,400	8,100	11,700	6,900
Poor or fair health	0	8%	41%	17%	5%	12%	17%	24%	16%
Poor physical health days	0	2.3	7.2	3.9	0.7	3.0	3.9	4.9	3.7
Low birthweight	107	3%	26%	8%	2%	6%	8%	11%	8%
Preventable hospital stays	38	471	33,333	4,828	1,867	2,765	4,648	6,877	4,520
Life expectancy	69.0	62.4	98.0	77.4	3.0	73.8	77.5	81.0	79.1
Premature age-adjusted mortality	61	120	1,150	410	110	280	390	550	340

Appendix G – SAS Programs and Procedural Syntax

Latent Transition Analysis Procedural Syntax

Table 24. Summary of PROC LTA Statements and Options

Syntax	Utility	Description
PROC LTA	**required**	Invokes the procedure
Options:		
DATA	**required**	Specifies SAS data file to be analyzed
VERBOSE_OUTPUT	*optional*	Shows starting values, parameter restrictions and maximum absolute deviation and loglikelihood at each iteration
OUTEST	*optional*	Saves parameter estimates to SAS data file in one record
OUTPARAM	*optional*	Saves parameter estimates to SAS data file
OUTPOST	*optional*	Saves posterior probabilities to SAS data file
NOPRINT	*optional*	Suppresses printing of output
START	*optional*	Allows user to provide starting values
RESTRICT	*optional*	Allows user to specify parameter restrictions for item-response probabilities
NOBETATEST	*optional*	Suppresses tests of significance for covariates
Statements:		
NSTATUS	**required**	Specifies number of latent statuses at each time
NTIMES	**required**	Specifies number of times of measurement
ITEMS	**required**	Declares variables that indicate latent status variable at each time
CATEGORIES	**required**	Specifies number of response categories in items
ID	*optional*	Declares identifier and other variables to retain in posterior probabilities SAS file
GROUPS	*optional*	Declares categorical grouping variable
GROUPNAMES	*optional*	Specifies a label for each group
COVARIATES1	*optional*	Declares variables to include as covariates for Time 1 status
COVARIATES2	*optional*	Declares variables to include as covariates for transitions
REFERENCE1	*optional*	Specifies latent status to be used as reference group in prediction from COVARIATES1
REFERENCE2	*optional*	Specifies latent statuses to be used as reference groups in prediction from COVARIATES2
BINARY1	*optional*	Specifies latent status to be used as comparison group in prediction from COVARIATES1, and that binary logistic regression is to be used
BINARY2	*optional*	Specifies latent statuses to be used as comparison groups in prediction from COVARIATES2, and that binary logistic regression is to be used
STABILIZE	*optional*	Invokes a stabilizing prior for the logistic regressions
FREQ	*optional*	Declares frequency count variable, to use when data are aggregated
ESTIMATION	*optional*	Specifies estimation procedure
SEED	**required ***	Specifies seed for random number generator
MEASUREMENT	*optional*	Invokes measurement invariance across groups and/or times
MAXITER	*optional*	Specifies maximum number of iterations
CRITERION	*optional*	Specifies convergence criterion for maximum absolute deviation

* SEED statement is required only if the START option is not included in the PROC LTA statement.

Data Cleaning and Preparation

Certain core SAS programs such as **Startup** (*defines LibNames, macro variables, and other global references*) and **Import** (i*mports all external datasets*) are not included in datasets, below. Restricted variable labels (e.g., individual NACCHO IDs) and other variables or outputs that may lead to respondent identification are redacted from SAS code.

Cleaning_Final

```
/*****************************************************************************************;
 Program Name  :        02_Cleaning_Final.sas
 Program Location:      ClnPgm
 Program Purpose :      Cleaning formatted data
 Created Date    :      01/09/2022 Jason Orr (v01)
 Modified Date   :      03/25/2024 Jason Orr (Final)
 Source Datasets :      Import.NACCHO_Prof2013to2019
 Output Datasets :      Cleaned.InitialCleaning, Cleaned.Missingness,
                        Cleaned.RemovedIncompletes, Cleaned.RemovedMissingActivities,
                        Cleaned.RemovedMissingServices, Cleaned.CoreDataset
 Hardcopy Output :      02_Cleaning Outputs.xlsx
*****************************************************************************************/

/*****************************************************************************************;
 Step 0: Program Setup (logins, libraries, common variable formats)
*****************************************************************************************/

*Call startup program with global vars (e.g., date, time, file), SAS libraries, etc.;
        *Root directory;
        %Let ROOT = C:\Users\jorr\Colostate\Engr-Sys Orr Dissertation - Documents\Analysis;
        %Include "&ROOT.\Programs\00_General\Startup.sas";



/*****************************************************************************************;
 Step 1: Modify NACCHO Profile 2016-2019 Dataset
*****************************************************************************************/

Data Cleaned.InitialCleaning
        (Keep =
                /*Core*/ &Var_Core. &Var_Survey.
                /*Governance*/ &Var_Colocation. &Var_Governance.
                /*Sharing*/ &Var_LHDList. &Var_ShareList. &Var_AgreementList. &Var_MeetList.
                        &Var_ExchangeList. &Var_NoneList. &Var_NAList. &Var_Sharing. &Var_CSCDen.
                /*Partners*/ &Var_Partners.
                /*Services*/ &Var_Delivered13. &Var_Contracted13. &Var_Delivered16.
                        &Var_Contracted16. &Var_Delivered19. &Var_Contracted19. &Var_Services.
                        &Var_ServicesDen. &Var_Counts.
        );
  Format
                /*Core*/ ID_YR $10.
```

```
            /*Governance*/ JurisGov Colocation $10. GovtClass7 $21. GovtClass4 $13.
            /*Sharing*/ LHD $9. &Var_CSCDen. 2.
            /*Partners*/ &Var_Partners. $9.
            /*Services*/ &Var_Services. 1. &Var_ServicesDen. &Var_Counts. 2.
        ;
    Set Import.NACCHO_Prof2013to2019;
        /*Input (20240325): var = 1995; all = 7518, 2013 = 2532, 2016 = 2533, 2019 = 2453*/

        /*****************************************************************************;
        Part 1: Data setup and corrections
        *****************************************************************************/

        *Fill in gaps of regions;
        If State in ("CT", "MA", "ME", "NH", "NJ", "NY", "PA", "VT") Then c0region_census = 1;
        Else If State in ("IA", "IL", "IN", "KS", "MI", "MN", "MO", "ND", "NE", "OH", "SD"
            , "WI") Then c0region_census = 2;
        Else If State in ("AL", "AR", "DC", "DE", "FL", "GA", "KY", "LA", "MD", "MS", "NC"
            , "OK", "SC", "TN", "TX", "VA", "WV") Then c0region_census = 3;
        Else If State in ("AK", "AZ", "CA", "CO", "HI", "ID", "MT", "NM", "NV", "OR", "UT"
            , "WA", "WY") Then c0region_census = 4;


**************************************REDACTED*******************************************


        /*****************************************************************************;
        Part 2: Creation of new variables
        *****************************************************************************/

        *Create new unique ID for respondent & year;
    ID_YR = CATX("_", NACCHOID, Year);


        /*****************************************************************************;
        Part 3: Centrality (local) - defining variable groupings
        *****************************************************************************/

        *Create new variable for jurisdiction;
        If c0jurisdiction in ("city", "county") Then JurisGov = "Sole";
        Else If c0jurisdiction = "city-county" Then JurisGov = "Vertical";
        Else If c0jurisdiction in ("multi-city", "multi-county") Then JurisGov = "Horizontal";


        *Create new variable for colocation/umbrella agency (assume DNK & E = Non);
        Colocation = "Non";
        If c2q501 = 1 Then Colocation = "Colocated";


        /*****************************************************************************;
        Part 4: Integration (state) - defining variable groupings
        *****************************************************************************/

        *Create ASTHO-NORC state-local governance classifications in 7 and 4 categories;
```

```
*Centralized & largely centralized state-local governance;
If State in ("AR", "DC", "DE", "HI", "MS", "NM", "RI", "SC", "VT") Then
	Do;
		GovtClass7 = "Centralized";
		GovtClass4 = "Centralized";
	End;
Else If State in ("AL", "LA", "NH", "SD", "VA") Then
	Do;
		GovtClass7 = "Largely Centralized";
		GovtClass4 = "Centralized";
	End;

*Shared & largely shared state-local governance;
Else If State in ("FL", "GA", "KY") Then
	Do;
		GovtClass7 = "Shared";
		GovtClass4 = "Shared";
	End;
Else If State in ("MD") Then
	Do;
		GovtClass7 = "Largely Shared";
		GovtClass4 = "Shared";
	End;

*Mixed state-local governance;
Else If State in ("AK", "ME", "OK", "PA", "TN", "WY") Then
	Do;
		GovtClass7 = "Mixed";
		GovtClass4 = "Mixed";
	End;

*Decentralized & largely decentralized state-local governance;
Else If State in ("NV", "TX") Then
	Do;
		GovtClass7 = "Largely Decentralized";
		GovtClass4 = "Decentralized";
	End;
Else If State in ("AZ", "CA", "CO", "CT", "IA", "ID", "IL", "IN", "KS", "MA"
	, "MI", "MN", "MO", "MT", "NC", "ND", "NE", "NJ", "NY", "OH", "OR", "UT"
	, "WA", "WI", "WV") Then
	Do;
		GovtClass7 = "Decentralized";
		GovtClass4 = "Decentralized";
	End;


/*******************************************************************************;
Part 5: Integration (CSC) - defining activity counts
*******************************************************************************/

*Define arrays for cross-sectoral collaborations;

	*Responses for shared personnel/resources (a);
	Array ShareList{*} &Ary_ShareList.;
	/*There is an error with 286 label suffix to keep in mind*/
```

```
	*Responses for written agreements (b);
	Array AgreementList{*} &Ary_AgreementList.;

	*Responses for regularly scheduled meetings (c);
	Array MeetList{*} &Ary_MeetList.;

	*Responses for exchange information (d);
	Array ExchangeList{*} &Ary_ExchangeList.;

	*Responses for no relationship (e);
	Array NoneList{*} &Ary_NoneList.;

	*Responses for not applicable (f);
	Array NAList{*} &Ary_NAList.;


*Initialize CSC arrays to "none";

	*Set initializing array;
	Array Partners{*} &Ary_Partners.;

	*Initialize the partner index variables to "None";
	Do m = 1 to dim(Partners);
		Partners[m] = "None";
	End;
	Drop m;


*Create denominator variable counts for each CSC array;
ShareDen = Dim(ShareList);
AgreementDen = Dim(AgreementList);
MeetDen = Dim(MeetList);
ExchangeDen = Dim(ExchangeList);
NoneDen = Dim(NoneList);
NADen = Dim(NAList);


*Create hierachy partner sharing according to CSPHS Spectrum of Sharing Arrangements;
Do r = 1 to dim(Partners);
	If ShareList[r] = 1 Then Partners[r] = "Shared";
	Else If AgreementList[r] = 1 Then Partners[r] = "Agreement";
	Else If MeetList[r] = 1 Then Partners[r] = "Informal";
	Else If ExchangeList[r] = 1 Then Partners[r] = "Informal";
	Else If NoneList[r] = 1 Then Partners[r] = "None";
	Else If NAList[r] = 1 Then Partners[r] = "None";
End;
Drop r;


/**********************************************************************************;
Part 6: Integration (CJS) - defining activity counts
**********************************************************************************/

*Define arrays for cross-jurisdictional sharing;
Array LHDShared{*} &Ary_LHDShared.;
Array LHDAgreement{*} &Ary_LHDAgreement.;
```

```
Array LHDInformal{*} &Ary_LHDInformal.;
Array LHDNone{*} &Ary_LHDNone.;


*Initialize LHD variable to "None";
LHD = "None";


*Create hierachy sharing according to Spectrum of Sharing Arrangements;

	*LHD sharing arrangements (assume function/delivery are shared);
	Do n = 1 to dim(LHDShared);
		If LHDShared[n] = 1 Then
			Do;
				LHD = "Shared";
				Leave;
			End;
	End;
	Drop n;

	Do o = 1 to dim(LHDAgreement);
		If LHDAgreement[o] = 1 Then
			Do;
				LHD = "Agreement";
				Leave;
			End;
	End;
	Drop o;

	Do p = 1 to dim(LHDInformal);
		If LHDInformal[p] = 1 Then
			Do;
				LHD = "Informal";
				Leave;
			End;
	End;
	Drop p;

	Do q = 1 to dim(LHDNone);
		If LHDNone[q] = 1 Then
			Do;
				LHD = "None";
				Leave;
			End;
	End;
	Drop q;


/**************************************************************************************;
Part 7: Differentiation (by year) - defining activity counts
**************************************************************************************/

*Define arrays for delivered(a)/contracted(b) services and tags ("Services*");

	*2013 NACCHO Profile arrays (questions and service categories in year);
```

```
			*Responses for services delivered by LHD in study year;
			Array Delivered13{*} &Ary_Delivered13.;

			*Responses for services contracted by LHD in study year;
			Array Contracted13{*} &Ary_Contracted13.;


		*2016 NACCHO Profile arrays (questions and service categories in year);

			*Responses for services delivered by LHD in study year;
			Array Delivered16{*} &Ary_Delivered16.;

			*Responses for services contracted by LHD in study year;
			Array Contracted16{*} &Ary_Contracted16.;


		*2019 NACCHO Profile arrays (questions and service categories in year);

			*Responses for services delivered by LHD in study year;
			Array Delivered19{*} &Ary_Delivered13.;

			*Responses for services contracted by LHD in study year;
			Array Contracted19{*} &Ary_Contracted19.;


	*Create denominator variable counts for each array;
	Delivered13Den = Dim(Delivered13);
	Contracted13Den = Dim(Contracted13);
	Delivered16Den = Dim(Delivered16);
	Contracted16Den = Dim(Contracted16);
	Delivered19Den = Dim(Delivered19);
	Contracted19Den = Dim(Contracted19);


	*Set initializing array of services group tags and initialize to 0;

		*Set initializing array of all services tags;
		Array Services{*} &Var_Services.;

		*Initialize each of the activity tags to 0;
		Do s = 1 to dim(Services);
			Services[s] = 0;
		End;
		Drop s;


	*Define arrays of services ordered for each NACCHO Profile study year (incl. dups);

		*Define 2013 study year activity tags (incl. dups like "IMM");
		Array Services13{*} &Ary_Services13Dup.;

		*Define 2016 study year activity tags (incl. dups like "IMM");
		Array Services16{*} &Ary_Services16Dup.;

		*Define 2019 study year activity tags (incl. dups like "IMM");
		Array Services19{*} &Ary_Services19Dup.;
```

```
*Produce counts of any services delivered or contracted in study year;

	*Indicate presence/absence of unique contracted & delivered service groups;

		*2013 NACCHO Profile activity counts;
		Do t = 1 to dim(Services13);
			If Delivered13[t] = 1 Then Services13[t] = 1;
			If Contracted13[t] = 1 Then Services13[t] = 1;
		End;
		Drop t;

		*2016 NACCHO Profile activity counts;
		Do u = 1 to dim(Services16);
			If Delivered16[u] = 1 Then Services16[u] = 1;
			If Contracted16[u] = 1 Then Services16[u] = 1;
		End;
		Drop u;

		*2019 NACCHO Profile activity counts;
		Do v = 1 to dim(Services19);
			If Delivered19[v] = 1 Then Services19[v] = 1;
			If Contracted19[v] = 1 Then Services19[v] = 1;
		End;
		Drop v;


/**********************************************************************************;
Part 8: Differentiation (by set) - defining activity counts
**********************************************************************************/

*Define arrays for all services categories;

	*Variable set for all services categories;
	Array ActList{*} &Ary_ActList.;

		*Variable set for population-based services;
		Array PopList{*} &Ary_PopList.;

			*Variable set for delivered services;
			Array PopDelList{*} &Ary_PopDelList.;

			*Variable set for policy services;
			Array PopPolList{*} &Ary_PopPolList.;

			*Variable set for prevention services;
			Array PopPreList{*} &Ary_PopPreList.;

			*Variable set for regulatory/inspection services;
			Array PopRegList{*} &Ary_PopRegList.;

			*Variable set for screening services;
			Array PopScrList{*} &Ary_PopScrList.;

			*Variable set for surveillance services;
```

```
				Array PopSurList{*} &Ary_PopSurList.;

			*Variable set for individual-based services;
			Array IndList{*} &Ary_IndList.;


*Define arrays for different years (deduplicated);

		*Variable sets for 2013 services categories (deduplicated);
			Array Services13Dedup{*} &Ary_Services13Dedup.;

		*Variable sets for 2016 services categories (deduplicated);
			Array Services16Dedup{*} &Ary_Services16Dedup.;

		*Variable sets for 2019 services categories (deduplicated);
			Array Services19Dedup{*} &Ary_Services19Dedup.;


*Variable counts for all service categories (overall in dataset);

		*Variable count for all service categories;

			*Variable count for population-based services;

				*Variable count for delivered services;
				PopDelDen = Dim(PopDelList);

				*Variable count for policy services;
				PopPolDen = Dim(PopPolList);

				*Variable count for prevention services;
				PopPreDen = Dim(PopPreList);

				*Variable count for regulatory/inspection services;
				PopRegDen = Dim(PopRegList);

				*Variable count for screening services;
				PopScrDen = Dim(PopScrList);

				*Variable count for surveillance services;
				PopSurDen = Dim(PopSurList);

				*Sum of population subsets;
				PopDen = PopDelDen + PopPolDen + PopPreDen + PopRegDen + PopScrDen
					+ PopSurDen;

			*Variable count for individual-based services;
			IndDen = Dim(IndList);

			*Sum of activity subsets;
			ActDen = PopDen + IndDen;


*Variable counts for all services categories (per survey year);

		*Variable counts for 2013 service categories;
```

```
		*Count of services for 2013 study year (deduplicated);
		ActDen13 = Dim(Services13Dedup);

		*Check if the items of PopList (pop. services) are in Services13;
		PopDen13 = 0;
		Do i = 1 to Dim(PopList);
			*Reset found flag for each PopList item;
			Found = 0;

			*Check if service in PopList exists in Services 13;
			Do j = 1 to Dim(Services13Dedup);
				If PopList[i] = Services13Dedup[j] Then Do;
					Found = 1;
					Leave;
				End;
			End;

			*Increment count only if a match is found;
			If Found Then PopDen13 = PopDen13 + 1;
		End;
		Drop i j Found;

	*Variable counts for 2016 service categories;

		*Count of services for 2016 study year (deduplicated);
		ActDen16 = Dim(Services16Dedup);

		*Check if the items of PopList (pop. services) are in Services16;
		PopDen16 = 0;
		Do i = 1 to Dim(PopList);
			*Reset found flag for each PopList item;
			Found = 0;

			*Check if service in PopList exists in Services 16;
			Do j = 1 to Dim(Services16Dedup);
				If PopList[i] = Services16Dedup[j] Then Do;
					Found = 1;
					Leave;
				End;
			End;

			*Increment count only if a match is found;
			If Found Then PopDen16 = PopDen16 + 1;
		End;
		Drop i j Found;

	*Variable counts for 2019 service categories;

		*Count of services for 2019 study year (deduplicated);
		ActDen19 = Dim(Services19Dedup);

		*Check if the items of PopList (pop. services) are in Services19;
		PopDen19 = 0;
		Do i = 1 to Dim(PopList);
			*Reset found flag for each PopList item;
```

```
					Found = 0;

					*Check if service in PopList exists in Services 19;
					Do j = 1 to Dim(Services19Dedup);
						If PopList[i] = Services19Dedup[j] Then Do;
							Found = 1;
							Leave;
						End;
					End;

					*Increment count only if a match is found;
					If Found Then PopDen19 = PopDen19 + 1;
				End;
				Drop i j Found;

Run;


*Reorder variables from dataset;
Data Cleaned.InitialCleaning;
	Retain
		/*Core*/ &Var_Core. &Var_Survey.
		/*Governance*/ &Var_Colocation. &Var_Governance.
		/*Sharing*/ &Var_LHDList. &Var_ShareList. &Var_AgreementList. &Var_MeetList.
			&Var_ExchangeList. &Var_NoneList. &Var_NAList. &Var_Sharing. &Var_CSCDen.
		/*Partners*/ &Var_Partners.
		/*Services*/ &Var_Delivered13. &Var_Contracted13. &Var_Delivered16.
			&Var_Contracted16. &Var_Delivered19. &Var_Contracted19. &Var_Services.
			&Var_ServicesDen. &Var_Counts.
	;
   Set Cleaned.InitialCleaning;

/*Output (20240325): var = 503; all = 7515, 2013 = 2530, 2016 = 2532, 2019 = 2453*/
/*Implications: removed unnecessary fields & variables*/
Run;



/*************************************************************************************;
 Step 2: Identify and characterize missingness of key fields
*************************************************************************************/

Data Cleaned.Missingness
	(Keep =
		/*Core*/ &Var_Core. &Var_Survey.
		/*Governance*/ &Var_Colocation. &Var_Governance.
		/*Sharing*/ &Var_LHDList. &Var_ShareList. &Var_AgreementList. &Var_MeetList.
			&Var_ExchangeList. &Var_NoneList. &Var_NAList. &Var_Sharing. &Var_CSCDen.
		/*Partners*/ &Var_Partners.
		/*Services*/ &Var_Delivered13. &Var_Contracted13. &Var_Delivered16.
			&Var_Contracted16. &Var_Delivered19. &Var_Contracted19. &Var_Services.
			&Var_ServicesDen. &Var_Counts.
		/*Missingness*/ &Var_Missingness. &Var_PropMiss.
	);

	Format
```

```
		/*Missingness*/ &Var_Missingness. 2. &Var_PropMiss. Best.2
	;

Set Cleaned.InitialCleaning;
	/*Input (20240325): var = 503; all = 7515, 2013 = 2530, 2016 = 2532, 2019 = 2453*/


	/**********************************************************************************;
	Part 1: Data setup
	**********************************************************************************/

	*Define arrays for reported collaborations and sharing;

		*Responses for shared personnel/resources (a);
		/*There is an error with 286 label suffix to keep in mind*/
		Array ShareList{*} &Ary_ShareList.;

		*Responses for written agreements (b);
		Array AgreementList{*} &Ary_AgreementList.;

		*Responses for regularly scheduled meetings (c);
		Array MeetList{*} &Ary_MeetList.;

		*Responses for exchange information (d);
		Array ExchangeList{*} &Ary_ExchangeList.;

		*Responses for no relationship (e);
		Array NoneList{*} &Ary_NoneList.;

		*Responses for not applicable (f);
		Array NAList{*} &Ary_NAList.;


	*Define arrays for delivered(a)/contracted(b) services and tags ("Services*");

		*2013 NACCHO Profile arrays (questions and service categories in year);

			*Responses for services delivered by LHD in study year;
			Array Delivered13{*} &Ary_Delivered13.;

			*Responses for services contracted by LHD in study year;
			Array Contracted13{*} &Ary_Contracted13.;


		*2016 NACCHO Profile arrays (questions and service categories in year);

			*Responses for services delivered by LHD in study year;
			Array Delivered16{*} &Ary_Delivered16.;

			*Responses for services contracted by LHD in study year;
			Array Contracted16{*} &Ary_Contracted16.;


		*2019 NACCHO Profile arrays (questions and service categories in year);

			*Responses for services delivered by LHD in study year;
```

```
        Array Delivered19{*} &Ary_Delivered13.;

        *Responses for services contracted by LHD in study year;
        Array Contracted19{*} &Ary_Contracted19.;


/*************************************************************************************;
Part 2: Identification of missingness
*************************************************************************************/

*Initialize missingness arrays;
MissingShare = 0;
MissingAgreement = 0;
MissingMeet = 0;
MissingExchange = 0;
MissingNone = 0;
MissingNA = 0;

MissingDelivered13 = 0;
MissingContracted13 = 0;
MissingDelivered16 = 0;
MissingContracted16 = 0;
MissingDelivered19 = 0;
MissingContracted19 = 0;


*Loop through collaboration arrays and count missing values;
/*Major trending break between 2013 and 2016/2019 for m13q's*/
Do a = 1 to dim(ShareList);
    If missing(ShareList[a]) Then MissingShare = MissingShare + 1;
End;
Drop a;

Do b = 1 to dim(AgreementList);
    If missing(AgreementList[b]) Then MissingAgreement = MissingAgreement + 1;
End;
Drop b;

Do c = 1 to dim(MeetList);
    If missing(MeetList[c]) Then MissingMeet = MissingMeet + 1;
End;
Drop c;

Do d = 1 to dim(ExchangeList);
    If missing(ExchangeList[d]) Then MissingExchange = MissingExchange + 1;
End;
Drop d;

Do e = 1 to dim(NoneList);
    If missing(NoneList[e]) Then MissingNone = MissingNone + 1;
End;
Drop e;

Do f = 1 to dim(NAList);
    If missing(NAList[f]) Then MissingNA = MissingNA + 1;
End;
```

```
	Drop f;


	*Loop through services arrays and count missing values;
	Do g = 1 to dim(Delivered13);
		If missing(Delivered13[g]) Then MissingDelivered13 = MissingDelivered13 + 1;
	End;
	Drop g;

	Do h = 1 to dim(Contracted13);
		If missing(Contracted13[h]) Then MissingContracted13 = MissingContracted13 + 1;
	End;
	Drop h;

	Do i = 1 to dim(Delivered16);
		If missing(Delivered16[i]) Then MissingDelivered16 = MissingDelivered16 + 1;
	End;
	Drop i;

	Do j = 1 to dim(Contracted16);
		If missing(Contracted16[j]) Then MissingContracted16 = MissingContracted16 + 1;
	End;
	Drop j;

	Do k = 1 to dim(Delivered19);
		If missing(Delivered19[k]) Then MissingDelivered19 = MissingDelivered19 + 1;
	End;
	Drop k;

	Do l = 1 to dim(Contracted19);
		If missing(Contracted19[l]) Then MissingContracted19 = MissingContracted19 + 1;
	End;
	Drop l;


	*Create missingness proportions for each set;
	PropMissShare = MissingShare / ShareDen;
	PropMissAgreement = MissingAgreement / AgreementDen;
	PropMissMeet = MissingMeet / MeetDen;
	PropMissExchange = MissingExchange / ExchangeDen;
	PropMissNone = MissingNone / NoneDen;
	PropMissNA = MissingNA / NADen;


	PropMissDelivered13 = MissingDelivered13 / Delivered13Den;
	PropMissContracted13 = MissingContracted13 / Contracted13Den;
	PropMissDelivered16 = MissingDelivered16 / Delivered16Den;
	PropMissContracted16 = MissingContracted16 / Contracted16Den;
	PropMissDelivered19 = MissingDelivered19 / Delivered19Den;
	PropMissContracted19 = MissingContracted19 / Contracted19Den;

Run;


*Reorder variables from dataset;
Data Cleaned.Missingness;
```

```
	Retain
		/*Core*/ &Var_Core. &Var_Survey.
		/*Governance*/ &Var_Colocation. &Var_Governance.
		/*Sharing*/ &Var_LHDList. &Var_ShareList. &Var_AgreementList. &Var_MeetList.
			&Var_ExchangeList. &Var_NoneList. &Var_NAList. &Var_Sharing. &Var_CSCDen.
		/*Partners*/ &Var_Partners.
		/*Services*/ &Var_Delivered13. &Var_Contracted13. &Var_Delivered16.
			&Var_Contracted16. &Var_Delivered19. &Var_Contracted19. &Var_Services.
			&Var_ServicesDen. &Var_Counts.
		/*Missings*/ &Var_Missingness. &Var_PropMiss.
	;
   Set Cleaned.Missingness;

/*Output (20240325): var = 527; all = 7515, 2013 = 2530, 2016 = 2532, 2019 = 2453*/
/*Implications: added missingness variables*/
Run;



/*************************************************************************************;
 Step 3: Removal of Incomplete Surveys
*************************************************************************************/

Data Cleaned.RemovedIncompletes
	(Keep =
		/*Core*/ &Var_Core. &Var_Survey.
		/*Governance*/ &Var_Colocation. &Var_Governance.
		/*Sharing*/ &Var_LHDList. &Var_ShareList. &Var_AgreementList. &Var_MeetList.
			&Var_ExchangeList. &Var_NoneList. &Var_NAList. &Var_Sharing. &Var_CSCDen.
		/*Partners*/ &Var_Partners.
		/*Services*/ &Var_Delivered13. &Var_Contracted13. &Var_Delivered16.
			&Var_Contracted16. &Var_Delivered19. &Var_Contracted19. &Var_Services.
			&Var_ServicesDen. &Var_Counts.
		/*Missings*/ &Var_Missingness. &Var_PropMiss.
	);
   Set Cleaned.Missingness;
	/*Input (20240526): var = 503; all = 7515, 2013 = 2530, 2016 = 2532, 2019 = 2453*/


	*Remove if Complete = 0;
	If Complete = 0 Then Delete;

/*Output (20240325): var = 527; all = 5423, 2013 = 1998, 2016 = 1929, 2019 = 1496*/
/*Implications: removed surveys indicated to be incomplete*/
Run;



/*************************************************************************************;
 Step 4: Removal of Missingness for Activities (>50% missingness excluded)
*************************************************************************************/
/**Only for diagnostics; Proc LTA can handle missingness**/

Data Cleaned.RemovedMissingActivities
	(Keep =
		/*Core*/ &Var_Core. &Var_Survey.
```

```
                    /*Governance*/ &Var_Colocation. &Var_Governance.
                    /*Sharing*/ &Var_LHDList. &Var_ShareList. &Var_AgreementList. &Var_MeetList.
                              &Var_ExchangeList. &Var_NoneList. &Var_NAList. &Var_Sharing. &Var_CSCDen.
                    /*Partners*/ &Var_Partners.
                    /*Services*/ &Var_Delivered13. &Var_Contracted13. &Var_Delivered16.
                              &Var_Contracted16. &Var_Delivered19. &Var_Contracted19. &Var_Services.
                              &Var_ServicesDen. &Var_Counts.
                    /*Missings*/ &Var_Missingness. &Var_PropMiss.
          );
   Set Cleaned.RemovedIncompletes;
          /*Input (20240325): var = 527; all = 5423, 2013 = 1998, 2016 = 1929, 2019 = 1496*/


          *Create proportions to evaluate missingness--remove if >50% missingness;
          If PropMissDelivered13 > 0.50 Then Delete;
          If PropMissContracted13 > 0.50 Then Delete;
          If PropMissDelivered16 > 0.50 Then Delete;
          If PropMissContracted16 > 0.50 Then Delete;
          If PropMissDelivered19 > 0.50 Then Delete;
          If PropMissContracted19 > 0.50 Then Delete;

/*Output (20240325): var = 527; all = 5240, 2013 = 1952, 2016 = 1877, 2019 = 1411*/
Run;



/*************************************************************************************;
 Step 5: Removal of Missingness for Sharing (>50% missingness excluded)
*************************************************************************************/
/**Only for diagnostics; Proc LTA can handle missingness**/

Data Cleaned.RemovedMissingSharing
          (Keep =
                    /*Core*/ &Var_Core. &Var_Survey.
                    /*Governance*/ &Var_Colocation. &Var_Governance.
                    /*Sharing*/ &Var_LHDList. &Var_ShareList. &Var_AgreementList. &Var_MeetList.
                              &Var_ExchangeList. &Var_NoneList. &Var_NAList. &Var_Sharing. &Var_CSCDen.
                    /*Partners*/ &Var_Partners.
                    /*Services*/ &Var_Delivered13. &Var_Contracted13. &Var_Delivered16.
                              &Var_Contracted16. &Var_Delivered19. &Var_Contracted19. &Var_Services.
                              &Var_ServicesDen. &Var_Counts.
                    /*Missings*/ &Var_Missingness. &Var_PropMiss.
          );
   Set Cleaned.RemovedMissingActivities;
          /*Input (20240325): var = 527; all = 5240, 2013 = 1952, 2016 = 1877, 2019 = 1411*/


          *Create proportions to evaluate missingness--remove if >50% missingness;
          If PropMissShare > 0.50 Then Delete;
          If PropMissAgreement > 0.50 Then Delete;
          If PropMissMeet > 0.50 Then Delete;
          If PropMissExchange > 0.50 Then Delete;
          If PropMissNone > 0.50 Then Delete;
          If PropMissNA > 0.50 Then Delete;

/*Output (20240325): var = 527; all = 823, 2013 = 0, 2016 = 472, 2019 = 351*/
```

```
Run;


/*****************************************************************************************;
 Step 6: Service Delivery Groupings
*****************************************************************************************/

Data Cleaned.ServiceDelivery
	(Keep =
		/*Core*/ &Var_Core. &Var_Survey.
		/*Governance*/ &Var_Governance.
		/*Sharing*/ &Var_Sharing. &Var_CSCDen.
		/*Partners*/ &Var_Partners. &Var_SDCounts. &Var_ShareIntegration.
		/*Services*/ &Var_Services. &Var_ServicesDen. &Var_Counts.
		/*Missings*/ &Var_PropMiss.
	);
	Format
		/*SD Counts*/ &Var_SDCounts. 2. &Var_ShareIntegration. $45.
	;

	Set Cleaned.RemovedIncompletes;
	/**Starting with RemovedIncompletes; Proc LTA can handle missingness**/
	/*Input (20240325): var = 180; all = 5423, 2013 = 1998, 2016 = 1929, 2019 = 1496*/

	/*****************************************************************************************;
	Part 1: Assess extent of sharing
	*****************************************************************************************/

	If Year in (2016, 2019) Then Do;

	/* Government Partners (Den = 9)
		/* Initialize count variable */
		Ct_Gov_Shared = 0;
		Ct_Gov_Agreement = 0;
		Ct_Gov_Informal = 0;

		/* Define array for variables in the set */
		Array GovPartList{*} &Ary_GovPartList.;
		/* Loop through each variable in the array */
		Do i = 1 to dim(GovPartList);
			/* Check if the variable contains specific text & increment count if found*/
			If GovPartList{i} = 'Shared' Then Do;
			  Ct_Gov_Shared + 1;
			End;
			Else If GovPartList{i} = 'Agreement' Then Do;
			  Ct_Gov_Agreement + 1;
			End;
			Else If GovPartList{i} = 'Informal' Then Do;
			  Ct_Gov_Informal + 1;
			End;
		End;

		/* Drop temporary index variable */
		Drop i;
```

```
/* Medical Partners (Den = 4)
	/* Initialize count variable */
	Ct_Med_Shared = 0;
	Ct_Med_Agreement = 0;
	Ct_Med_Informal = 0;

	/* Define array for variables in the set */
	Array MedPartList{*} &Ary_MedPartList.;
	/* Loop through each variable in the array */
	Do i = 1 to dim(MedPartList);
		/* Check if the variable contains specific text & increment count if found*/
		If MedPartList{i} = 'Shared' Then Do;
		  Ct_Med_Shared + 1;
		End;
		Else If MedPartList{i} = 'Agreement' Then Do;
		  Ct_Med_Agreement + 1;
		End;
		Else If MedPartList{i} = 'Informal' Then Do;
		  Ct_Med_Informal + 1;
		End;
	End;

	/* Drop temporary index variable */
	Drop i;

/* Social Partners (Den = 4)
	/* Initialize count variable */
	Ct_Soc_Shared = 0;
	Ct_Soc_Agreement = 0;
	Ct_Soc_Informal = 0;

	/* Define array for variables in the set */
	Array SocPartList{*} &Ary_SocPartList.;
	/* Loop through each variable in the array */
	Do i = 1 to dim(SocPartList);
		/* Check if the variable contains specific text & increment count if found*/
		If SocPartList{i} = 'Shared' Then Do;
		  Ct_Soc_Shared + 1;
		End;
		Else If SocPartList{i} = 'Agreement' Then Do;
		  Ct_Soc_Agreement + 1;
		End;
		Else If SocPartList{i} = 'Informal' Then Do;
		  Ct_Soc_Informal + 1;
		End;
	End;

	/* Drop temporary index variable */
	Drop i;

/* Private Partners (Den = 5)
	/* Initialize count variable */
	Ct_Pvt_Shared = 0;
	Ct_Pvt_Agreement = 0;
	Ct_Pvt_Informal = 0;
```

```
		/* Define array for variables in the set */
		Array PvtPartList{*} &Ary_PvtPartList.;
		/* Loop through each variable in the array */
		Do i = 1 to dim(PvtPartList);
			/* Check if the variable contains specific text & increment count if found*/
			If PvtPartList{i} = 'Shared' Then Do;
			  Ct_Pvt_Shared + 1;
			End;
			Else If PvtPartList{i} = 'Agreement' Then Do;
			  Ct_Pvt_Agreement + 1;
			End;
			Else If PvtPartList{i} = 'Informal' Then Do;
			  Ct_Pvt_Informal + 1;
			End;
		End;

		/* Drop temporary index variable */
		Drop i;

	*Total counts;
		Ct_Shared = Ct_Gov_Shared + Ct_Med_Shared + Ct_Soc_Shared + Ct_Pvt_Shared;
		Ct_Agreement = Ct_Gov_Agreement + Ct_Med_Agreement + Ct_Soc_Agreement
			+ Ct_Pvt_Agreement;
		Ct_Informal = Ct_Gov_Informal + Ct_Med_Informal + Ct_Soc_Informal
			+ Ct_Pvt_Informal;
		Ct_Sharing = Ct_Shared + Ct_Agreement + Ct_Informal;

	End;

	/*********************************************************************************;
	Part 2: Assess mix of sharing and integration
	*********************************************************************************/

	*Sharing and Integration;
	ShareExtent = ".";
	Integration = ".";
	ShareIntegration = ".";

	If Ct_Sharing > 0 Then Do;
		*Extent of sharing;
			Do;
				If Ct_Sharing > 16 Then ShareExtent = "Extensive Sharing";
				Else If Ct_Sharing > 8 Then ShareExtent = "Moderate Sharing";
				Else If Ct_Sharing > 0 Then ShareExtent = "Limited Sharing";
			End;

		*Extent of integration;
			Do;
				If (Ct_Shared / Ct_Sharing) > 0.50 Then Integration = "High Integration";
				Else If (Ct_Agreement / Ct_Sharing) > 0.50 Then Integration =
					"Moderate Integration";
				Else If (Ct_Informal / Ct_Sharing) > 0.50 Then Integration =
					"Minimal Integration";
				Else If ((Ct_Shared + Ct_Agreement) / Ct_Sharing) > 0.75 Then
					Integration = "High Integration";
				Else If ((Ct_Shared + Ct_Agreement) / Ct_Sharing) > 0.50 Then
```

```
                    Integration = "Moderate Integration";
                Else If ((Ct_Shared + Ct_Agreement) / Ct_Sharing) > 0.0 Then
                    Integration = "Minimal Integration";
            End;

            ShareIntegration = catx(' with ', ShareExtent, Integration);

    End;
Run;


Data Cleaned.ServiceDelivery;
    Retain
        /*Core*/ &Var_Core. &Var_Survey.
        /*Governance*/ &Var_Governance.
        /*Sharing*/ &Var_Sharing. &Var_CSCDen.
        /*Partners*/ &Var_Partners. &Var_SDCounts. &Var_ShareIntegration.
        /*Services*/ &Var_Services. &Var_ServicesDen. &Var_Counts.
        /*Missings*/ &Var_PropMiss.
    ;
    Set Cleaned.ServiceDelivery;
/*Output (20240325): var = 199; all = 5423, 2013 = 1998, 2016 = 1929, 2019 = 1496*/
Run;



/*************************************************************************************;
 Step 7: Services Groupings
*************************************************************************************/

Data Cleaned.Services
    (Keep =
        /*Core*/ &Var_Core. &Var_Survey.
        /*Governance*/ &Var_Governance. c0govcat2
        /*Sharing*/ &Var_Sharing. &Var_CSCDen.
        /*Partners*/ &Var_Partners. &Var_SDCounts. &Var_ShareIntegration.
        /*Services*/ &Var_Services. &Var_ServicesDen. &Var_Counts. &Var_ServicesNum.
            &Var_Differentiation.
        /*Missings*/ &Var_PropMiss.
    );
    Format
        /*Services Counts*/       &Var_ServicesNum. 2. &Var_Differentiation. $40. c0govcat2 $10.
    ;

    Set Cleaned.ServiceDelivery;
    /*Input (20240325): var = 199; all = 5423, 2013 = 1998, 2016 = 1929, 2019 = 1496*/

    /*********************************************************************************;
    Part 1: Define services arrays and initialize
    *********************************************************************************/

    /* Define arrays */
    *Variable set for delivered services;
    Array PopDelList{*} &Ary_PopDelList.;

    *Variable set for policy services;
```

```
Array PopPolList{*} &Ary_PopPolList.;

*Variable set for prevention services;
Array PopPreList{*} &Ary_PopPreList.;

*Variable set for regulatory/inspection services;
Array PopRegList{*} &Ary_PopRegList.;

*Variable set for screening services;
Array PopScrList{*} &Ary_PopScrList.;

*Variable set for surveillance services;
Array PopSurList{*} &Ary_PopSurList.;

*Variable set for individual-based services;
Array IndList{*} &Ary_IndList.;

/* Initialize sums */
PopDelNum = 0;
PopPolNum = 0;
PopPreNum = 0;
PopRegNum = 0;
PopScrNum = 0;
PopSurNum = 0;
IndNum = 0;


/*********************************************************************************;
Part 2: Assess distribution of services
*********************************************************************************/

/* For each year and set, loop through array elements and accumulate sum */

Do i = 1 to dim(PopDelList);
   PopDelNum + PopDelList{i};
End;

Do j = 1 to dim(PopPolList);
   PopPolNum + PopPolList{j};
End;

Do k = 1 to dim(PopPreList);
   PopPreNum + PopPreList{k};
End;

Do l = 1 to dim(PopRegList);
   PopRegNum + PopRegList{l};
End;

Do m = 1 to dim(PopScrList);
   PopScrNum + PopScrList{m};
End;

Do n = 1 to dim(PopSurList);
   PopSurNum + PopSurList{n};
End;
```

```
Do o = 1 to dim(IndList);
   IndNum + IndList{o};
End;


/**********************************************************************************;
Part 3: Create services grouping counts
**********************************************************************************/

PopNum = PopDelNum + PopPolNum + PopPreNum + PopRegNum + PopScrNum + PopSurNum;
SvcsNum = PopNum + IndNum;


/**********************************************************************************;
Part 4: Establish annual differentiation of services
**********************************************************************************/

*Sharing and Integration;
Differentiation = ".";
PopMix = ".";
DifferentiationMix = ".";

*Extent of differentiation;
If Year = 2013 Then Do;
        Do;
                If (SvcsNum / ActDen13) > 0.66 Then Differentiation = "Comprehensive";
                Else If (SvcsNum / ActDen13) > 0.33 Then Differentiation = "Conventional";
                Else If (SvcsNum / ActDen13) > 0.0 Then Differentiation = "Limited";
        End;

        Do;
                If (PopNum / PopDen13) > 0.75 Then PopMix = "Population Focus";
                Else If (PopNum / PopDen13) > 0.25 Then PopMix = "Balanced Focus";
                Else If (PopNum / PopDen13) > 0.0 Then PopMix = "Clinical Focus";
        End;
End;

If Year = 2016 Then Do;
        Do;
                If (SvcsNum / ActDen16) > 0.66 Then Differentiation = "Comprehensive";
                Else If (SvcsNum / ActDen16) > 0.33 Then Differentiation = "Conventional";
                Else If (SvcsNum / ActDen16) > 0.0 Then Differentiation = "Limited";
        End;

        Do;
                If (PopNum / PopDen16) > 0.75 Then PopMix = "Population Focus";
                Else If (PopNum / PopDen16) > 0.25 Then PopMix = "Balanced Focus";
                Else If (PopNum / PopDen16) > 0.0 Then PopMix = "Clinical Focus";
        End;
End;

If Year = 2019 Then Do;
        Do;
                If (SvcsNum / ActDen19) > 0.66 Then Differentiation = "Comprehensive";
                Else If (SvcsNum / ActDen19) > 0.33 Then Differentiation = "Conventional";
```

```
			Else If (SvcsNum / ActDen19) > 0.0 Then Differentiation = "Limited";
		End;

		Do;
			If (PopNum / PopDen19) > 0.75 Then PopMix = "Population Focus";
			Else If (PopNum / PopDen19) > 0.25 Then PopMix = "Balanced Focus";
			Else If (PopNum / PopDen19) > 0.0 Then PopMix = "Clinical Focus";
		End;
	End;

	If Differentiation NE "." and PopMix NE "." Then DifferentiationMix =
		catx(' with ', Differentiation, PopMix);


	/*************************************************************************************;
	Part 5: Recode c0govcat values
	*************************************************************************************/

	*Recode NACCHO governance variables;
	If c0govcat = 1 Then c0govcat2 = 'State';
	Else If c0govcat = 2 Then c0govcat2 = 'Local';
	Else If c0govcat = 3 Then c0govcat2 = 'Shared';

Run;


Data Cleaned.Services;
	Retain
		/*Core*/ &Var_Core. &Var_Survey.
		/*Governance*/ &Var_Governance. c0govcat2
		/*Sharing*/ &Var_Sharing. &Var_CSCDen.
		/*Partners*/ &Var_Partners. &Var_SDCounts. &Var_ShareIntegration.
		/*Services*/ &Var_Services. &Var_ServicesDen. &Var_Counts. &Var_ServicesNum.
			&Var_Differentiation.
		/*Missings*/ &Var_PropMiss.
	;
	Set Cleaned.Services;
/*Output (20240325): var = 212; all = 5423, 2013 = 1998, 2016 = 1929, 2019 = 1496*/
Run;



/*************************************************************************************;
 Step 8: Output Core Dataset of Key Variables
*************************************************************************************/

Data Cleaned.CoreComplete
	(Keep =
		/*Core*/ &Var_Core. &Var_Survey.
		/*Governance*/ &Var_Governance. c0govcat2
		/*Sharing*/ &Var_Sharing. &Var_CSCDen.
		/*Partners*/ &Var_Partners. &Var_SDCounts. &Var_ShareIntegration.
		/*Services*/ &Var_Services. &Var_ServicesDen. &Var_Counts. &Var_ServicesNum.
			&Var_Differentiation.
		/*Missings*/ &Var_PropMiss.
	);
```

```
            Set Cleaned.Services;

/*Output (20240325): var = 212; all = 5423, 2013 = 1998, 2016 = 1929, 2019 = 1496*/
Run;

Proc Sort
            Data = Cleaned.CoreComplete;
            By NACCHOID Year;
Run;



/*******************************************************************************************;
 Step 8: Export datasets to Excel (unformatted)
*******************************************************************************************/

            /*******************************************************************************************;
            Part 1: Create a macro to export a dataset with metadata information
            *******************************************************************************************/

            %Macro ExcelExport(Data =, Sheet =);
               /* Get the number of variables and observations */
               Proc SQL NoPrint;
                  Select NVar into :num_vars
                  From Dictionary.Tables
                  Where LibName = 'Cleaned' and memname = upcase("&data.");

                  Select NObs into :num_obs
                  From Dictionary.Tables
                  Where LibName = 'Cleaned' and memname = upcase("&data.");
               Quit;

               /* Write the metadata information to the Excel sheet */
               Data _null_;
                  File Print;
                  Put "Dataset Filename: &data.";
                  Put "Date of Export: &DateStamp.";
                  Put "Number of Variables: &num_vars.";
                  Put "Number of Observations: &num_obs.";
               Run;

                     /* Export to Excel */
               ODS Excel Options(sheet_name = "&sheet." start_at="2,1");

               /* Export the dataset */
               Proc Print Data = &data. NoObs;
               run;

            %MEnd ExcelExport;


            /*******************************************************************************************;
            Part 2: Create Excel file
            *******************************************************************************************/

            ODS Excel File = "&ROOT.\Hardcopy\Excel\Cleaned_Cleaning_&DateStamp..xlsx"
```

```
	Options(sheet_interval = "none");

/*********************************************************************************;
Part 3: Export datasets with metadata
*********************************************************************************/

%ExcelExport(data = Cleaned.InitialCleaning, sheet = InitialCleaning);
%ExcelExport(data = Cleaned.Missingness, sheet = Missingness);
%ExcelExport(data = Cleaned.RemovedIncompletes, sheet = RemovedIncompletes);
%ExcelExport(data = Cleaned.RemovedMissingActivities, sheet = RemovedMissingActivities);
%ExcelExport(data = Cleaned.RemovedMissingSharing, sheet = RemovedMissingSharing);
%ExcelExport(data = Cleaned.ServiceDelivery, sheet = ServiceDelivery);
%ExcelExport(data = Cleaned.Services, sheet = Services);
%ExcelExport(data = Cleaned.CoreComplete, sheet = CoreComplete);

ODS Excel Close;
```

TypologyPrep_Final

```
/*******************************************************************************************;
 Program Name  :        02_TypologyPrep_Final.sas
 Program Location:      TypoPgm
 Program Purpose :      Latent Transition Analysis data prep
 Created Date    :      08/15/2023 Jason Orr (v01)
 Modified Date   :      04/05/2024 Jason Orr (Final)
 Source Datasets :      Cleaned.CoreComplete
 Output Datasets :      TypoData.LTAPrep, TypoData.LTADataset
 Hardcopy Output :      TypoData_Typology_&DateStamp..xlsx
*******************************************************************************************/

/*******************************************************************************************;
 Step 0: Program Setup (logins, libraries, common variable formats)
*******************************************************************************************/

*Call startup program with global vars (e.g., date, time, file), SAS libraries, etc.;
        *Root directory;
        %Let ROOT = C:\Users\jorr\Colostate\Engr-Sys Orr Dissertation - Documents\Analysis;
        %Include "&ROOT.\Programs\00_General\Startup.sas";



/*******************************************************************************************;
 Step 1: Prepare dataset for LTA
*******************************************************************************************/

/*Calculate mean and standard deviation of population variable*/
Proc Means
        Data = Cleaned.CoreComplete Mean StD;
   Var c0population;
   Output Out = Pop_Stats Mean = Mean_Population StD = StD_Population;
Run;


/*Setup LTA dataset*/
Data TypoData.LTAPrep
        (Keep =
                /*Core*/ Year &Var_CoreLTA. StateNo c0populationStD GovtClassNo
                /*Governance*/ c0govcatLTA c0jurisdictionLTA JurisGovLTA
                /*Sharing*/ ColocationLTA LHDLTA ShareExtentLTA IntegrationLTA
                                ShareIntegrationLTA
                /*Services*/ DifferentiationLTA PopMixLTA DifferentiationMixLTA);
        Format
                /*Core*/ StateNo 2. c0populationStD 8.2 GovtClassNo 1.
                /*Governance*/ c0govcatLTA c0jurisdictionLTA JurisGovLTA 1.
                /*Sharing*/ ColocationLTA LHDLTA ShareExtentLTA IntegrationLTA
                        ShareIntegrationLTA 1.
                /*Services*/ DifferentiationLTA PopMixLTA DifferentiationMixLTA 1.;
        Set Cleaned.CoreComplete;
        /*Input (20240405): var = 212; all = 5423, 2013 = 1998, 2016 = 1929, 2019 = 1496*/

        /*****************************************************************************************;
        Part 1: Recode values for LTA
```

```
*********************************************************************************/

If _N_ = 1 Then Set Pop_Stats;
c0populationStD = (c0population - Mean_Population) / StD_Population;

Select (State);
	When ('AL') StateNo = 01; When ('AK') StateNo = 02; When ('AZ') StateNo = 04;
	When ('AR') StateNo = 05; When ('CA') StateNo = 06; When ('CO') StateNo = 08;
	When ('CT') StateNo = 09; When ('DE') StateNo = 10; When ('DC') StateNo = 11;
	When ('FL') StateNo = 12; When ('GA') StateNo = 13; When ('HI') StateNo = 15;
	When ('ID') StateNo = 16; When ('IL') StateNo = 17; When ('IN') StateNo = 18;
	When ('IA') StateNo = 19; When ('KS') StateNo = 20; When ('KY') StateNo = 21;
	When ('LA') StateNo = 22; When ('ME') StateNo = 23; When ('MD') StateNo = 24;
	When ('MA') StateNo = 25; When ('MI') StateNo = 26; When ('MN') StateNo = 27;
	When ('MS') StateNo = 28; When ('MO') StateNo = 29; When ('MT') StateNo = 30;
	When ('NE') StateNo = 31; When ('NV') StateNo = 32; When ('NH') StateNo = 33;
	When ('NJ') StateNo = 34; When ('NM') StateNo = 35; When ('NY') StateNo = 36;
	When ('NC') StateNo = 37; When ('ND') StateNo = 38; When ('OH') StateNo = 39;
	When ('OK') StateNo = 40; When ('OR') StateNo = 41; When ('PA') StateNo = 42;
	When ('RI') StateNo = 44; When ('SC') StateNo = 45; When ('SD') StateNo = 46;
	When ('TN') StateNo = 47; When ('TX') StateNo = 48; When ('UT') StateNo = 49;
	When ('VT') StateNo = 50; When ('VA') StateNo = 51; When ('WA') StateNo = 53;
	When ('WV') StateNo = 54; When ('WI') StateNo = 55; When ('WY') StateNo = 56;
	When ('PR') StateNo = 72; When ('VI') StateNo = 78;
End;

Select (GovtClass4);
	When ('Decentralized') GovtClassNo = 1;
	When ('Mixed') GovtClassNo = 2;
	When ('Shared') GovtClassNo = 3;
	When ('Centralized') GovtClassNo = 4;
	Otherwise GovtClassNo = '.';
End;

Select (c0govcat2);
	When ('State') c0govcatLTA = 1;
	When ('Local') c0govcatLTA = 2;
	When ('Shared') c0govcatLTA = 3;
	Otherwise c0govcatLTA = '.';
End;

Select (c0jurisdiction);
	When ('city') c0jurisdictionLTA = 1;
	When ('county') c0jurisdictionLTA = 2;
	When ('city-county') c0jurisdictionLTA = 3;
	When ('multi-city') c0jurisdictionLTA = 4;
	When ('multi-county') c0jurisdictionLTA = 5;
	Otherwise c0jurisdictionLTA = '.';
End;

Select (JurisGov);
	When ('Sole') JurisGovLTA = 1;
	When ('Vertical') JurisGovLTA = 2;
	When ('Horizontal') JurisGovLTA = 3;
	Otherwise JurisGovLTA = '.';
End;
```

```
Select (Colocation);
		When ('Non') ColocationLTA = 1;
		When ('Colocated') ColocationLTA = 2;
		Otherwise ColocationLTA = '.';
End;

Select (LHD);
		When ('None') LHDLTA = 1;
		When ('Informal') LHDLTA = 2;
		When ('Agreement') LHDLTA = 3;
		When ('Shared') LHDLTA = 4;
		Otherwise LHDLTA = '.';
End;

Select (ShareExtent);
		When ('Limited Sharing') ShareExtentLTA = 1;
		When ('Moderate Sharing') ShareExtentLTA = 2;
		When ('Extensive Sharing') ShareExtentLTA = 3;
		Otherwise ShareExtentLTA = '.';
End;

Select (Integration);
		When ('Minimal Integration') IntegrationLTA = 1;
		When ('Moderate Integration') IntegrationLTA = 2;
		When ('High Integration') IntegrationLTA = 3;
		Otherwise IntegrationLTA = '.';
End;

Select (ShareIntegration);
		When ('Limited Sharing with Minimal Integration') ShareIntegrationLTA = 1;
		When ('Limited Sharing with Moderate Integration') ShareIntegrationLTA = 2;
		When ('Limited Sharing with High Integration') ShareIntegrationLTA = 3;
		When ('Moderate Sharing with Minimal Integration') ShareIntegrationLTA = 4;
		When ('Moderate Sharing with Moderate Integration') ShareIntegrationLTA = 5;
		When ('Moderate Sharing with High Integration') ShareIntegrationLTA = 6;
		When ('Extensive Sharing with Minimal Integration') ShareIntegrationLTA = 7;
		When ('Extensive Sharing with Moderate Integration') ShareIntegrationLTA = 8;
		When ('Extensive Sharing with High Integration') ShareIntegrationLTA = 9;
		Otherwise ShareIntegrationLTA = '.';
End;

Select (Differentiation);
		When ('Limited') DifferentiationLTA = 1;
		When ('Conventional') DifferentiationLTA = 2;
		When ('Comprehensive') DifferentiationLTA = 3;
		Otherwise DifferentiationLTA = '.';
End;

Select (PopMix);
		When ('Clinical Focus') PopMixLTA = 1;
		When ('Balanced Focus') PopMixLTA = 2;
		When ('Population Focus') PopMixLTA = 3;
		Otherwise PopMixLTA = '.';
End;
```

```
	Select (DifferentiationMix);
		When ('Limited with Clinical Focus') DifferentiationMixLTA = 1;
		When ('Limited with Balanced Focus') DifferentiationMixLTA = 2;
		When ('Limited with Population Focus') DifferentiationMixLTA = 3;
		When ('Conventional with Clinical Focus') DifferentiationMixLTA = 4;
		When ('Conventional with Balanced Focus') DifferentiationMixLTA = 5;
		When ('Conventional with Population Focus') DifferentiationMixLTA = 6;
		When ('Comprehensive with Clinical Focus') DifferentiationMixLTA = 7;
		When ('Comprehensive with Balanced Focus') DifferentiationMixLTA = 8;
		When ('Comprehensive with Population Focus') DifferentiationMixLTA = 9;
		Otherwise DifferentiationMixLTA = '.';
	End;

Run;

Data TypoData.LTAPrep;
	Retain
		/*Core*/ Year &Var_CoreLTA. StateNo c0populationStD GovtClassNo
		/*Governance*/ c0govcatLTA c0jurisdictionLTA JurisGovLTA
		/*Sharing*/ ColocationLTA LHDLTA ShareExtentLTA IntegrationLTA
				ShareIntegrationLTA
		/*Services*/ DifferentiationLTA PopMixLTA DifferentiationMixLTA;
	Set TypoData.LTAPrep;
/*Output (20240405): var = 20; all = 5423, 2013 = 1998, 2016 = 1929, 2019 = 1496*/
Run;

Proc Sort
	Data = TypoData.LTAPrep;
	By NACCHOID Year;
Run;



/*******************************************************************************************;
 Step 2: Restructure dataset and merge for LTA
*******************************************************************************************/

Data TypoData.LTADataset
	(Keep =
		/*Core*/ &Var_CoreLTA. &Var_CoreLTAPop.
		/*Governance*/ &Var_GovLTA13. &Var_GovLTA16. &Var_GovLTA19.
		/*Service Delivery*/ &Var_SDLTA13. &Var_SDLTA16. &Var_SDLTA19.
		/*Differentiation*/ &Var_SvcLTA13. &Var_SvcLTA16. &Var_SvcLTA19.);
	Format
		/*Core*/ &Var_CoreLTAPop. 8.2
		/*Governance*/ &Var_GovLTA13. &Var_GovLTA16. &Var_GovLTA19. 1.
		/*Service Delivery*/ &Var_SDLTA13. &Var_SDLTA16. &Var_SDLTA19. 1.
		/*Differentiation*/ &Var_SvcLTA13. &Var_SvcLTA16. &Var_SvcLTA19. 1.;

	/*Input (20240405): var = 20; all = 5423, 2013 = 1998, 2016 = 1929, 2019 = 1496*/
	Merge
		TypoData.LTAPrep (Where = (Year = 2013)
			rename = (
				c0populationStD = c0population13
				c0govcatLTA = c0govcat13
				c0jurisdictionLTA = c0jurisdiction13
```

```
                    JurisGovLTA = JurisGov13
                    ColocationLTA = Colocation13
                    LHDLTA = LHD13
                    ShareExtentLTA = ShareExtent13
                    IntegrationLTA = Integration13
                    ShareIntegrationLTA = ShareIntegration13
                    DifferentiationLTA = Differentiation13
                    PopMixLTA = PopMix13
                    DifferentiationMixLTA = DifferentiationMix13))
        TypoData.LTAPrep (Where = (Year = 2016)
            rename = (
                    c0populationStD = c0population16
                    c0govcatLTA = c0govcat16
                    c0jurisdictionLTA = c0jurisdiction16
                    JurisGovLTA = JurisGov16
                    ColocationLTA = Colocation16
                    LHDLTA = LHD16
                    ShareExtentLTA = ShareExtent16
                    IntegrationLTA = Integration16
                    ShareIntegrationLTA = ShareIntegration16
                    DifferentiationLTA = Differentiation16
                    PopMixLTA = PopMix16
                    DifferentiationMixLTA = DifferentiationMix16))
        TypoData.LTAPrep (Where = (Year = 2019)
            rename = (
                    c0populationStD = c0population19
                    c0govcatLTA = c0govcat19
                    c0jurisdictionLTA = c0jurisdiction19
                    JurisGovLTA = JurisGov19
                    ColocationLTA = Colocation19
                    LHDLTA = LHD19
                    ShareExtentLTA = ShareExtent19
                    IntegrationLTA = Integration19
                    ShareIntegrationLTA = ShareIntegration19
                    DifferentiationLTA = Differentiation19
                    PopMixLTA = PopMix19
                    DifferentiationMixLTA = DifferentiationMix19));
    By NACCHOID;

Run;


*Remove observations without requisite data;
Data TypoData.LTADataset;
    Set TypoData.LTADataset;
    If c0population13 = "."     and c0population16 = "." Then Delete;
    If c0population13 = "."     and c0population19 = "." Then Delete;
    If c0population16 = "."     and c0population19 = "." Then Delete;
/*Output (20240405): var = 43; all = 1920, 2013 = 1776, 2016 = 1790, 2019 = 1417*/
Run;


Data TypoData.LTADataset;
    Retain
        /*Core*/ &Var_CoreLTA. &Var_CoreLTAPop.
        /*Governance*/ &Var_GovLTA13. &Var_GovLTA16. &Var_GovLTA19.
```

```
            /*Service Delivery*/ &Var_SDLTA13. &Var_SDLTA16. &Var_SDLTA19.
            /*Differentiation*/ &Var_SvcLTA13. &Var_SvcLTA16. &Var_SvcLTA19.;
        Set TypoData.LTADataset;

/*Output (20240405): var = 43; all = 1920, 2013 = 1776, 2016 = 1790, 2019 = 1417*/
Run;



/***************************************************************************************;
 Step 3: Export core datasets to Excel (unformatted)
***************************************************************************************/

    /***************************************************************************************;
    Part 1: Create a macro to export a dataset with metadata information
    ***************************************************************************************/

    %Macro ExcelExport(Data =, Sheet =);
      /* Get the number of variables and observations */
      Proc SQL NoPrint;
        Select NVar into :num_vars
        From Dictionary.Tables
        Where LibName = 'TypoData' and memname = upcase("&data.");

        Select NObs into :num_obs
        From Dictionary.Tables
        Where LibName = 'TypoData' and memname = upcase("&data.");
      Quit;

      /* Write the metadata information to the Excel sheet */
      Data _null_;
        File Print;
        Put "Dataset Filename: &data.";
        Put "Date of Export: &DateStamp.";
        Put "Number of Variables: &num_vars.";
        Put "Number of Observations: &num_obs.";
      Run;

            /* Export to Excel */
      ODS Excel Options(sheet_name = "&sheet." start_at="2,1");

      /* Export the dataset */
      Proc Print Data = &data. NoObs;
      run;

    %MEnd ExcelExport;


    /***************************************************************************************;
    Part 2: Create Excel file
    ***************************************************************************************/

    ODS Excel File = "&ROOT.\Hardcopy\Excel\TypoData_Typology_&DateStamp..xlsx"
            Options(sheet_interval = "none");
```

```
/*********************************************************************************;
Part 3: Export datasets with metadata
*********************************************************************************/

%ExcelExport(data = TypoData.LTAPrep, sheet = LTAPrep);
%ExcelExport(data = TypoData.LTADataset, sheet = LTADataset);

ODS Excel Close;
```

Latent Transition Analysis

LTASpecification_Final

```
/*************************************************************************************;
 Program Name  :        LTASpecification_Final.sas
 Program Location:      TypoPgm
 Program Purpose :      Latent Transition Analysis model specification
 Created Date     :     09/30/2023 Jason Orr (v01)
 Modified Date    :     04/21/2014 Jason Orr (Final)
 Source Datasets :      TypoData.LTADataset
 Output Datasets :      Per Run: ModSpec.Est_&Run_ID, ModSpec.Param_&Run_ID
                                          , ModSpec.Results_&Run_ID
                                   ModSpec.All_Results, ModSpec.Valid_Results
 Hardcopy Output :      02_Model Specification Outputs.xlsx
*************************************************************************************/

/*************************************************************************************;
 Step 0: Program Setup (logins, libraries, common variable formats)
*************************************************************************************/

*Call startup program with global vars (e.g., date, time, file), SAS libraries, etc.;
        *Root directory;
        %Let ROOT = C:\Users\jorr\Colostate\Engr-Sys Orr Dissertation - Documents\Analysis;
        %Include "&ROOT.\Programs\00_General\Startup.sas";



/*************************************************************************************;
 Step 1: Create macro to generate differential list of items based on year (NTIMES)
*************************************************************************************/

%Macro Generate_Items_List(NTIMES);
   %Local ITEMS_List i;
   %Let ITEMS_List =;

   %If &NTIMES = 2 %Then %Do;
      %Let ITEMS_List =
                          c0govcat16 c0jurisdiction16 Colocation16 LHD16
                          c0govcat19 c0jurisdiction19 Colocation19 LHD19;
   %End;
   %Else %If &NTIMES = 3 %Then %Do;
      %Let ITEMS_List =
                          c0govcat13 c0jurisdiction13 Colocation13 LHD13
                          c0govcat16 c0jurisdiction16 Colocation16 LHD16
                          c0govcat19 c0jurisdiction19 Colocation19 LHD19;
   %End;
   &ITEMS_List
%MEnd;



/*************************************************************************************;
 Step 2: Create macro to run the LTA based on different parameters
*************************************************************************************/
```

```
%Macro Run_LTA(NSTATUS, NTIMES, SEED, ITEMS);
	%Let Run_ID = &NSTATUS._&NTIMES._&SEED;
   %Let ITEMS = %Generate_Items_List(&NTIMES);

	Proc LTA
		Data = TypoData.LTADataset
			OutEst = ModSpec.Est_&Run_ID /**parameter estimates and fit statistics**/
			OutParam = ModSpec.Param_&Run_ID /**parameter estimates alt format**/
			NoPrint
			;
		NStatus /**Specifies number of latent statuses.**/
			&NSTATUS;
		NTimes /**Specifies the number of times.**/
			&NTIMES;
		Items /**Declares variables that indicate dynamic latent status variable.**/
			&ITEMS;
		Categories /**Specifies number of response categories in items for all times.**/
			3 5 2 4;
		/**ID**/ /**Declares ID and other variables to retain in Post output.**/
			/**variable;**/
		Seed /**Specifies for random number generator (required if no START option).**/
			&SEED; /** Random six-digit seed **/
		Maxiter /**Specifies maximum number of iterations.**/
			5000; /** Default: 5000 **/
		Criterion /**Specifies convergence criterion for maximum absolute deviation.**/
			0.000001; /** Default: 0.000001**/
	Run;
%MEnd;


/**************************************************************************************;
 Step 3: Create macro to generate differential list of ESTLS* based on statuses (NSTATUS)
**************************************************************************************/

%Macro Generate_ESTLS_List(NSTATUS);
   %Local i ESTLS_List;
   %Let ESTLS_List =;
   %Do i = 1 %To &NSTATUS;
      %Let ESTLS_List = &ESTLS_List ESTLS&i;
      %If &i ne &NSTATUS %Then %Let ESTLS_List = &ESTLS_List,;
   %End;
   &ESTLS_List
%MEnd;


/**************************************************************************************;
 Step 4: Create macro to Extract relevant results from each LTA output
**************************************************************************************/

%Macro Compare_Results(NSTATUS, NTIMES, SEED);
	%Let Run_ID = &NSTATUS._&NTIMES._&SEED.;
   %Let ESTLS_List = %Generate_ESTLS_List(&NSTATUS);
```

```
   Proc SQL;
      Create Table ModSpec.Results_&Run_ID as
               Select
                                 "&Run_ID" as Run,
                                 G_SQUARED, AIC, BIC, DEGREES_OF_FREEDOM,
                                 /*Extract DELTA parameters from Param output*/
                                 (Select Max(&ESTLS_List) from ModSpec.Param_&Run_ID Where PARAM
= 'DELTA')
                                         as Max_Delta
               From ModSpec.Est_&Run_ID;
   Quit;
%MEnd;


/************************************************************************************;
 Step 4: Create macro to test combinations of parameters
************************************************************************************/

%Macro Test_Combinations;
        %Let NSTATUS_List = 04 05 06 07 08 09 10 11 12;
   %Let NTIMES_List = 2 3;
   %Let SEED_List = 123456 654321;

        /*********************************************************************************;
        Part 1: Loop through all combinations of parameters
        *********************************************************************************/

   %Do i = 1 %to %SysFunc(countw(&NSTATUS_List));
      %Let NSTATUS = %Scan(&NSTATUS_List, &i);
      %Do j = 1 %to %SysFunc(countw(&NTIMES_List));
         %Let NTIMES = %Scan(&NTIMES_List, &j);
         %Do k = 1 %to %SysFunc(countw(&SEED_List));
            %Let SEED = %Scan(&SEED_List, &k);

            /* Run LTA */
            %Run_LTA(&NSTATUS, &NTIMES, &SEED);

            /* Compare results */
            %Compare_Results(&NSTATUS, &NTIMES, &SEED);
         %End;
      %End;
   %End;


        /*********************************************************************************;
        Part 2: Aggregate all results
        *********************************************************************************/

   Proc SQL;
      Create Table ModSpec.All_Results as
         %Do i = 1 %to %SysFunc(countw(&NSTATUS_List));
            %Let NSTATUS = %Scan(&NSTATUS_List, &i);
            %Do j = 1 %to %SysFunc(countw(&NTIMES_List));
               %Let NTIMES = %Scan(&NTIMES_List, &j);
               %Do k = 1 %to %SysFunc(countw(&SEED_List));
```

```
                %Let SEED = %Scan(&SEED_List, &k);
                %Let Run_ID = &NSTATUS._&NTIMES._&SEED;

                %If &i = 1 and &j = 1 and &k = 1 %Then %Do;
                   Select * from ModSpec.Results_&Run_ID
                %End;

                %Else %Do;
                   Union all
                   Select * from ModSpec.Results_&Run_ID
                %End;
             %End;
          %End;
       %End;
   Quit;

   Proc Sort
      Data = ModSpec.All_Results;
         By Run;
   Run;


         /*************************************************************************************;
         Part 4: Remove invalid results
         *************************************************************************************/

         Data ModSpec.Valid_Results;
            Set ModSpec.All_Results;
                  If G_SQUARED < 0 Then Delete;
                        If DEGREES_OF_FREEDOM < 0 Then Delete;
                  If G_SQUARED > DEGREES_OF_FREEDOM Then Delete;
         Run;
%MEnd;



/*************************************************************************************;
 Step 5: Run the macro to test all combinations and aggregate results
*************************************************************************************/

%Test_Combinations;

/****
         Best Model 06_2_654321 (20240421): 6 latent statuses; 2 times (2016/2019);
         all governance and most service delivery items: local governance, jurisdiction type,
         HHS colocation, LHD cross-jurisdictional integration; arbitrary 6-digit seed (654321).

         Outputs: DoF - 14,244; G2 - 1,085; AIC - 1,395; BIC - 2,257; Max Delta - 0.52

         Conclusion: The present model offers the best fit across parameters and the least
         variation across parameters when different seed values are selected. A 6-status 2-time
         model, excluding cross-sectoral sharing and integration, was needed for stability.
****/
```

LTABaseModel _Final

```
/*******************************************************************************************;
 Program Name  :        LTABaseModel_Final.sas
 Program Location:      TypoPgm
 Program Purpose :      Latent Transition Analysis base model output
 Created Date     :     10/12/2023 Jason Orr (v01)
 Modified Date    :     05/22/2024 Jason Orr (Final)
 Source Datasets :      TypoData.LTADataset
 Output Datasets :      TypoData.BaseModel_Post, TypoData.BaseModel_Est
                                 , TypoData.BaseModel_Param
 Hardcopy Output :      Per Model(*): TypoData_BaseModel_&DateStamp..xlsx
*******************************************************************************************/

/*******************************************************************************************;
 Step 0: Program Setup (logins, libraries, common variable formats)
*******************************************************************************************/

*Call startup program with global vars (e.g., date, time, file), SAS libraries, etc.;
        *Root directory;
        %Let ROOT = C:\Users\jorr\Colostate\Engr-Sys Orr Dissertation - Documents\Analysis;
        %Include "&ROOT.\Programs\00_General\Startup.sas";



/*******************************************************************************************;
 Step 1: Run Latent Transition Analysis Base Model
*******************************************************************************************/

/** 6-class, 2-time (2016-2019), governance & service delivery variables, excluding
        cross-sectoral sharing and integration **/

PROC LTA
        DATA = TypoData.LTADataset
                /** OUTPUT OPTIONS **/
                OutPost = TypoData.BaseModel_Post /**posterior probabilities dataset**/
                OutEst = TypoData.BaseModel_Est /**parameter estimates and some fit
                        statistics dataset**/
                OutParam = TypoData.BaseModel_Param /**parameter estimates dataset**/
                NoPrint /**no output be shown on the screen**/;
        Title1 "6-Class 2-Year LTA Model for Local Health Departments";
        Title2 "Governance & Service Delivery Factors (w/o cross-sectoral), No Covariates";

        /** CORE VARIABLES & PARAMETERS **/
        NStatus /**Specifies number of latent statuses.**/
                6;
        NTimes /**Specifies the number of times.**/
                2;
        Items /**Declares variables that indicate dynamic latent status variable.**/
                c0govcat16 c0jurisdiction16 Colocation16 LHD16
                c0govcat19 c0jurisdiction19 Colocation19 LHD19;
        Categories /**Specifies number of response categories in items for all times.**/
                3 5 2 4;
        ID /**Declares identifier and other variables to retain in posterior probabilities
                file.**/
```

```
            &Var_CoreLTA. JurisGov16 c0population16 JurisGov19 c0population19;
        Seed /**Specifies for random number generator (required if no START option).**/
            654321; /** Random six-digit seed **/
        Maxiter /**Specifies maximum number of iterations.**/
            5000; /** Default: 5000 **/
        Criterion /**Specifies convergence criterion for maximum absolute deviation.**/
            0.000001; /** Default: 0.000001**/
Run;
Title;


/*******************************************************************************************;
 Step 2: Export Base Model datasets to Excel (unformatted)
*******************************************************************************************/

        /*************************************************************************************;
        Part 1: Create a macro to export a dataset with metadata information
        *************************************************************************************/

        %Macro ExcelExport(Library =, Dataset =);
           %Let lib = %UpCase(&Library.);
           %Let dset = %UpCase(&Dataset.);

           /* Get the number of variables and observations */
           Proc SQL Noprint;
              Select Count(*) into :num_vars
              From Dictionary.Columns
              Where LibName = "&lib." and MemName = "&dset.";

              Select Count(*) into :num_obs
              From &Library..&Dataset.;
           Quit;

           /* Export the metadata and dataset to the specified Excel sheet */
           ODS Excel Options(sheet_name = "&Dataset." start_at = "1,1");

           /* Write the metadata information to the Excel sheet */
           Data _null_;
              File Print;
              Put "Dataset Filename: &Dataset.";
              Put "Date of Export: &DateStamp.";
              Put "Number of Variables: &num_vars.";
              Put "Number of Observations: &num_obs.";
              Put " "; /* Blank row */
           Run;

           /* Export the dataset starting from row 6 */
           Proc Print Data = &Library..&Dataset. NoObs;
           Run;

        %MEnd ExcelExport;

        /*************************************************************************************;
        Part 2: Export datasets with metadata
        *************************************************************************************/
```

```
ODS Excel File = "&ROOT.\Hardcopy\Excel\TypoData_BaseModel_&DateStamp..xlsx";

%ExcelExport(Library = TypoData, Dataset = BaseModel_Post);
%ExcelExport(Library = TypoData, Dataset = BaseModel_Est);
%ExcelExport(Library = TypoData, Dataset = BaseModel_Param);

ODS Excel Close;


/**********************************************************************************;

Part 3: Correlation Testing

**********************************************************************************/


proc corr data=TypoData.LTADataset;

   var c0govcat16 c0jurisdiction16 Colocation16 LHD16;

run;


proc corr data=TypoData.LTADataset;

   var c0govcat19 c0jurisdiction19 Colocation19 LHD19;

run;
```

LTABaseModel_Covariates_Final

```
/*****************************************************************************************;
 Program Name  :        LTABaseModel_Covariates_Final.sas
 Program Location:      TypoPgm
 Program Purpose :      Latent Transition Analysis base model with covariates output
 Created Date    :      01/24/2023 Jason Orr (v01)
 Modified Date   :      05/22/2024 Jason Orr (Final)
 Source Datasets :      TypoData.LTADataset
 Output Datasets :      TypoData.BaseModelCov_Post, TypoData.BaseModelCov_Est
                                  , TypoData.BaseModelCov_Param
 Hardcopy Output :      Per Model(*): TypoData_BaseModelCov_&DateStamp..xlsx
*****************************************************************************************/

/*****************************************************************************************;
 Step 0: Program Setup (logins, libraries, common variable formats)
*****************************************************************************************/

*Call startup program with global vars (e.g., date, time, file), SAS libraries, etc.;
        *Root directory;
        %Let ROOT = C:\Users\jorr\Colostate\Engr-Sys Orr Dissertation - Documents\Analysis;
        %Include "&ROOT.\Programs\00_General\Startup.sas";



/*****************************************************************************************;
 Step 1: Run Latent Transition Analysis Base Model with Covariates
*****************************************************************************************/

/** 6-class, 2-time (2016-2019), governance & service delivery variables, excluding
        cross-sectoral sharing and integration **/

PROC LTA
        DATA = TypoData.LTADataset
                /** OUTPUT OPTIONS **/
                OutPost = TypoData.BaseModelCov_Post /**posterior probabilities dataset**/
                OutEst = TypoData.BaseModelCov_Est /**parameter estimates and some fit statistics
                        dataset**/
                OutParam = TypoData.BaseModelCov_Param /**parameter estimates dataset**/
                NoPrint /**no output be shown on the screen**/
                ;

        Title1 "6-Class 2-Year LTA Model for Local Health Departments";
        Title2 "Governance & Service Delivery Factors (w/o cross-sectoral) with Covariates";

        /** CORE VARIABLES & PARAMETERS **/
        NStatus /**Specifies number of latent statuses.**/
                6;
        NTimes /**Specifies the number of times.**/
                2;
        Items /**Declares variables that indicate dynamic latent status variable.**/
                c0govcat16 c0jurisdiction16 Colocation16 LHD16
                c0govcat19 c0jurisdiction19 Colocation19 LHD19
                ;
        Categories /**Specifies number of response categories in items for all times.**/
```

```
            3 5 2 4;
    ID /**Declares identifier and other variables to retain in posterior probabilities
            file.**/
            &Var_CoreLTA. JurisGov16 c0population16 JurisGov19 c0population19;

    /** COVARIATES 1 **/
    Covariates1 /**Declares variables to include as covariates for time 1.**/
            StateNo c0population16 ShareExtent16 Integration16 Differentiation16 PopMix16;
    Beta Prior = /**Invokes a stabilizing prior for the logistic regressions
            relating covariates to class memberships. Prior strength must be specified.**/
            1;

    /** OTHER PARAMETERS & FUNCTIONS **/
    Seed /**Specifies for random number generator (required if no START option).**/
            654321; /** Random six-digit seed **/
    Maxiter /**Specifies maximum number of iterations.**/
            5000; /** Default: 5000 **/
    Criterion /**Specifies convergence criterion for maximum absolute deviation.**/
            0.000001; /** Default: 0.000001**/
Run;
Title;


/*****************************************************************************************;
 Step 2: Export Base Model datasets to Excel (unformatted)
*****************************************************************************************/

    /*************************************************************************************;
    Part 1: Create a macro to export a dataset with metadata information
    *************************************************************************************/

    %Macro ExcelExport(Library =, Dataset =);
      %let lib = %upcase(&Library.);
      %let dset = %upcase(&Dataset.);

      /* Get the number of variables and observations */
      Proc SQL Noprint;
        Select Count(*) into :num_vars
        From dictionary.columns
        Where LibName = "&lib." and MemName = "&dset.";

        Select Count(*) into :num_obs
        From &Library..&Dataset.;
      Quit;

      /* Export the metadata and dataset to the specified Excel sheet */
      ODS Excel Options(sheet_name = "&Dataset." start_at="1,1");

      /* Write the metadata information to the Excel sheet */
      Data _null_;
        File Print;
        Put "Dataset Filename: &Dataset.";
        Put "Date of Export: &DateStamp.";
        Put "Number of Variables: &num_vars.";
        Put "Number of Observations: &num_obs.";
```

```
    Put " "; /* Blank row */
  Run;

  /* Export the dataset starting from row 6 */
  Proc Print Data = &Library..&Dataset. NoObs;
  Run;

%MEnd ExcelExport;

/*********************************************************************************;
Part 2: Export datasets with metadata
*********************************************************************************/
ODS Excel File = "&ROOT.\Hardcopy\Excel\TypoData_BaseModelCov_&DateStamp..xlsx";

%ExcelExport(Library = TypoData, Dataset = BaseModelCov_Post);
%ExcelExport(Library = TypoData, Dataset = BaseModelCov_Est);
%ExcelExport(Library = TypoData, Dataset = BaseModelCov_Param);

ODS Excel Close;
```

Ordinal Regression Analyses

LTABaseModel_Regression_Final

```
/******************************************************************************************;
 Program Name  :        LTABaseModel_Regression_Final.sas
 Program Location:      TypoPgm
 Program Purpose :      Ordinal Regression Analysis
 Created Date     :     01/24/2023 Jason Orr (v01)
 Modified Date    :     05/22/2024 Jason Orr (Final)
 Source Datasets :      Import.FIPS_Denominator_LHD2022_New
 Output Datasets :      Cleaned.FIPS_Denominator_LHD2022
                                , TypoData.BaseModel_Post_Regress
 Hardcopy Output :
******************************************************************************************/

/******************************************************************************************;
 Step 0: Program Setup (logins, libraries, common variable formats)
******************************************************************************************/

*Call startup program with global vars (e.g., date, time, file), SAS libraries, etc.;
        *Root directory;
        %Let ROOT = C:\Users\jorr\Colostate\Engr-Sys Orr Dissertation - Documents\Analysis;
        %Include "&ROOT.\Programs\00_General\Startup.sas";



/******************************************************************************************;
 Step 1: Creating core typology & CHRR dataset
******************************************************************************************/

/*Setting leading zeroes for FIPS*/
Data Cleaned.FIPS_Denominator_LHD2022;
        Set Import.FIPS_Denominator_LHD2022_New;
        Format State $2. County $3.;

   State = STATEA;
   County = COUNTYA_1;
Run;


/*Creating 5-digit FIPS*/
Data Cleaned.FIPS_Denominator_LHD2022;
        Set Cleaned.FIPS_Denominator_LHD2022;
        Format FIPS $5.;

   StateFIPS = put(input(State, 2.), z2.);
   CountyFIPS = put(input(County, 3.), z3.);
   FIPS = cats(StateFIPS, CountyFIPS);
Run;


/*Creating CHRR file with NACCHOID*/
Proc SQL;
   Create Table Cleaned.CHRRNACCHOID as
```

```
		Select a.*, b.FIPS, b.NACCHO_ID, b.lhd_name
		from Import.CHRR2019 as a
		left join Cleaned.FIPS_Denominator_LHD2022 as b
		on a.fipscode = b.FIPS;
quit;


/*Creating CHRR & LTA posterior file*/
Proc SQL;
   Create Table TypoData.BaseModel_Post_FIPS as
		Select a.*, b.*
		from TypoData.BaseModel_Post as a
		left join Cleaned.CHRRNACCHOID as b
		on a.NACCHOID = b.NACCHO_ID;
quit;


/*Narrowing dataset*/
Data TypoData.BaseModel_Post_Regress;
	Retain
		/*Core*/ &Var_CoreLTA. &Var_CoreLTAPop.
		/*Governance*/ &Var_GovLTA19.
		/*Service Delivery*/ &Var_SDLTA19.
		/*Differentiation*/ &Var_SvcLTA19.
		/*LTA*/ POSTPROBSTATUS1T2 POSTPROBSTATUS2T2 POSTPROBSTATUS3T2
POSTPROBSTATUS4T2
			POSTPROBSTATUS5T2 POSTPROBSTATUS6T2
		/*CHRR*/ fipscode FIPS
			v001_rawvalue /*Premature death raw value*/
			v002_rawvalue /*Poor or fair health raw value*/
			v036_rawvalue /*Poor physical health days raw value*/
			v037_rawvalue /*Low birthweight raw value*/
			v005_rawvalue /*Preventable hospital stays raw value*/
			v147_rawvalue /*Life expectancy raw value*/
			v127_rawvalue /*Premature age-adjusted mortality raw value*/
			v104_rawvalue /*Communicable disease raw value*/
		;
	Set TypoData.BaseModel_Post_FIPS;

Run;


/*Narrowing dataset*/
Data TypoData.BaseModel_Post_Regress
	(Keep =
		/*Core*/ &Var_CoreLTA. &Var_CoreLTAPop.
		/*Governance*/ &Var_GovLTA19.
		/*Service Delivery*/ &Var_SDLTA19.
		/*Differentiation*/ &Var_SvcLTA19.
		/*LTA*/ POSTPROBSTATUS1T2 POSTPROBSTATUS2T2 POSTPROBSTATUS3T2
POSTPROBSTATUS4T2
			POSTPROBSTATUS5T2 POSTPROBSTATUS6T2
		/*CHRR*/ fipscode FIPS
			v001_rawvalue /*Premature death raw value*/
			v002_rawvalue /*Poor or fair health raw value*/
			v036_rawvalue /*Poor physical health days raw value*/
```

```
                    v037_rawvalue /*Low birthweight raw value*/
                    v005_rawvalue /*Preventable hospital stays raw value*/
                    v147_rawvalue /*Life expectancy raw value*/
                    v127_rawvalue /*Premature age-adjusted mortality raw value*/
               LatentState
               );
       Set TypoData.BaseModel_Post_FIPS;
       Format LatentState 1.;

       Array post_probs[6] POSTPROBSTATUS1T2 POSTPROBSTATUS2T2 POSTPROBSTATUS3T2
POSTPROBSTATUS4T2
    POSTPROBSTATUS5T2 POSTPROBSTATUS6T2;

  max_prob = max(of post_probs[*]);

  do i = 1 to dim(post_probs);
    if post_probs[i] = max_prob then do;
      LatentState = i;
      leave;
    end;
  end;

  /* Properly handle missing values in the array */
  if max_prob = . then LatentState = .;

  /* Delete observations where JurisGov19 is 0 */
  if JurisGov19 = 0 then delete;

  drop i max_prob;


Run;




/*************************************************************************************;
 Step 2: Regression analysis
*************************************************************************************/
/*OLD*/
proc reg
       data = TypoData.BaseModel_Post_Regress;
  model LatentState = v001_rawvalue v002_rawvalue v036_rawvalue v037_rawvalue
                    v005_rawvalue v147_rawvalue v127_rawvalue;
run;
quit;

proc logistic data=TypoData.BaseModel_Post_Regress;
  class LatentState (ref='1');  /* Specify the reference category for the ordinal variable */
  model LatentState = v001_rawvalue v002_rawvalue v036_rawvalue v037_rawvalue
                    v005_rawvalue v147_rawvalue v127_rawvalue / link = clogit;
  /* Alternatively, for individual models, run separate regressions */
  /* model response = var1 / link=clogit; */
  /* model response = var2 / link=clogit; */
run;
```

```
proc logistic data=TypoData.BaseModel_Post_Regress;
   model LatentState = v001_rawvalue v002_rawvalue v036_rawvalue v037_rawvalue v005_rawvalue
v147_rawvalue v127_rawvalue / link=glogit;
   /* This example assumes using the generalized logit model, which can handle violations of the proportional odds
assumption */
run;
```

Appendix H – Detailed Results for Model Specification

Analysis of Base Model Variables

Period 1 (2016) Correlation Analysis

Table 25. Descriptive Statistics for Base Model Variables (2016)

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
c0govcat16	1790	1.88	0.53	3367	1	3
c0jurisdiction16	1790	2.21	1.00	3950.00	1	5
Colocation16	1790	1.19	0.39	2131	1	2
LHD16	1790	1.06	0.34	1902	1	4

Table 26. Correlation Matrix for Base Model Variables (2016)

	c0govcat16	c0jurisdiction16	Colocation16	LHD16
	Pearson Correlation Coefficients, N = 1790 Prob > |r| under H0: Rho=0			
c0govcat16	1.00	-0.12 <.0001	-0.03 0.24	0.02 0.34
c0jurisdiction16	-0.12 <.0001	1.00	0.04 0.12	0.05 0.03
Colocation16	-0.03 0.24	0.04 0.12	1.00	-0.03 0.14
LHD16	0.02 0.34	0.05 0.03	-0.03 0.14	1.00

Period 2 (2019) Correlation Analysis

Table 27. Descriptive Statistics for Base Model Variables (2019)

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
c0govcat16	1417	1.88	0.55	2666	1	3
c0jurisdiction16	1417	2.18	0.97	3094.00	1	5
Colocation16	1417	1.21	0.40	1708	1	2
LHD16	1417	1.04	0.26	1478	1	4

Table 28. Correlation Matrix for Base Model Variables (2019)

	c0govcat19	c0jurisdiction19	Colocation19	LHD19
	Pearson Correlation Coefficients, N = 1790 Prob > |r| under H0: Rho=0			
c0govcat16	1.00	-0.02 0.39	-0.02 0.51	0.01 0.67

c0jurisdiction16	-0.02 0.39	1.00	0.03 0.23	0.02 0.47
Colocation16	-0.02 0.51	0.03 0.23	1.00	0.02 0.53
LHD16	0.01 0.67	0.02 0.47	0.02 0.53	1.00

Parameter Estimates for Base Model

Table 29. Parameter Estimates for Base Model (OUTPARAM)

Parameter	Group	Variable	Time	Status	Response Category	Est. Latent Status 1	Est. Latent Status 2	Est. Latent Status 3	Est. Latent Status 4	Est. Latent Status 5	Est. Latent Status 6
DELTA	1		1	.	.	0.13	0.07	0.52	0.16	0.08	0.04
TAU	1		1	1	.	1.00	0.00	0.00	0.00	0.00	0.00
TAU	1		1	2	.	0.00	1.00	0.00	0.00	0.00	0.00
TAU	1		1	3	.	0.00	0.00	1.00	0.00	0.00	0.00
TAU	1		1	4	.	0.00	0.00	0.00	1.00	0.00	0.00
TAU	1		1	5	.	0.00	0.00	0.00	0.00	1.00	0.00
TAU	1		1	6	.	0.00	0.00	0.00	0.00	0.00	1.00
RHO	1	*c0govcat16*	1	.	1	0.03	0.00	0.00	0.97	0.12	0.77
RHO	1	*c0jurisdiction16*	1	.	1	1.00	0.00	0.00	0.00	0.00	0.00
RHO	1	*Colocation16*	1	.	1	0.84	0.76	0.82	0.80	0.80	0.71
RHO	1	*LHD16*	1	.	1	0.99	0.91	0.97	0.96	0.95	0.88
RHO	1	*c0govcat16*	1	.	2	0.97	0.00	1.00	0.00	0.88	0.00
RHO	1	*c0jurisdiction16*	1	.	2	0.00	1.00	1.00	1.00	0.00	0.00
RHO	1	*Colocation16*	1	.	2	0.16	0.24	0.18	0.20	0.20	0.29
RHO	1	*LHD16*	1	.	2	0.00	0.07	0.01	0.04	0.03	0.11
RHO	1	*c0govcat16*	1	.	3	0.00	1.00	0.00	0.03	0.00	0.23
RHO	1	*c0jurisdiction16*	1	.	3	0.00	0.00	0.00	0.00	0.02	0.03
RHO	1	*LHD16*	1	.	3	0.01	0.02	0.01	0.00	0.02	0.00
RHO	1	*c0jurisdiction16*	1	.	4	0.00	0.00	0.00	0.00	0.43	0.00
RHO	1	*LHD16*	1	.	4	0.00	0.00	0.01	0.00	0.00	0.01
RHO	1	*c0jurisdiction16*	1	.	5	0.00	0.00	0.00	0.00	0.55	0.97
RHO	1	*c0govcat19*	2	.	1	0.03	0.00	0.00	1.00	0.01	0.67
RHO	1	*c0jurisdiction19*	2	.	1	1.00	0.00	0.01	0.00	0.00	0.00
RHO	1	*Colocation19*	2	.	1	0.83	0.82	0.78	0.83	0.77	0.67
RHO	1	*LHD19*	2	.	1	0.99	0.93	0.98	0.96	0.98	0.94
RHO	1	*c0govcat19*	2	.	2	0.97	0.00	1.00	0.00	0.99	0.00
RHO	1	*c0jurisdiction19*	2	.	2	0.00	1.00	0.99	0.99	0.00	0.00
RHO	1	*Colocation19*	2	.	2	0.17	0.18	0.22	0.17	0.23	0.33
RHO	1	*LHD19*	2	.	2	0.01	0.03	0.01	0.04	0.01	0.06
RHO	1	*c0govcat19*	2	.	3	0.00	1.00	0.00	0.00	0.00	0.33
RHO	1	*c0jurisdiction19*	2	.	3	0.00	0.00	0.00	0.00	0.01	0.04
RHO	1	*LHD19*	2	.	3	0.01	0.03	0.01	0.01	0.01	0.00
RHO	1	*c0jurisdiction19*	2	.	4	0.00	0.00	0.00	0.00	0.41	0.00

RHO	1	*LHD19*	2	.	4	0.00	0.00	0.00	0.00	0.00	0.00
RHO	1	*c0jurisdiction19*	2	.	5	0.00	0.00	0.00	0.01	0.58	0.96

Appendix I – Detailed Results for Covariate Analysis

Analysis of Base Model Covariates

Covariate Correlation Analysis (2016)

Variables: StateNo, c0population16, ShareExtent16, Integration16, Differentiation16, PopMix16

Table 30. Descriptive Statistics for Base Model Covariates (2016)

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
StateNo	1920	28.68	15.30	55062	1	56
c0population16	1790	0.01	1.02	23.55	-0.34	22.25
ShareExtent16	460	2.55	0.61	1175	1	3
Integration16	460	1.18	0.47	545	1	3
Differentiation16	1776	2.22	0.60	3946	1	3
PopMix16	1775	2.13	0.44	3778	1	3

Table 31. Correlation Matrix for Base Model Covariates (2016)

Variable	StateNo	c0population16	ShareExtent16	Integration16	Differentiation16	PopMix16
Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations						
StateNo	1.00 1920	-0.02 0.32 1790	0.10 0.03 460	0.00 0.95 460	0.06 0.02 1776	0.00 0.95 1775
c0population16	-0.02 0.32 1790	1.00 1790	0.16 0.00 460	0.11 0.02 460	0.13 <.0001 1776	0.13 <.0001 1775
ShareExtent16	0.10 0.03 460	0.16 0.00 460	1.00 460	-0.04 0.41 460	0.31 <.0001 457	0.24 <.0001 457
Integration16	0.00 0.95 460	0.11 0.02 460	-0.04 0.41 460	1.00 460	0.09 0.04 457	0.12 0.01 457
Differentiation16	0.06 0.02 1776	0.13 <.0001 1776	0.31 <.0001 457	0.09 0.04 457	1.00 1776	0.68 <.0001 1775
PopMix16	0.00 0.95 1775	0.13 <.0001 1775	0.24 <.0001 457	0.12 0.01 457	0.68 <.0001 1775	1.00 1775

Appendix J – Detailed Results for Ordinal Regression of Latent Status

Cumulative Logit Model

Figure 6. Cumulative Logit Model Information

Model Information	
Data Set	TYPODATA.BASEMODEL_POST_REGRESS
Response Variable	Latent Status
Number of Response Levels	6
Model	cumulative logit
Optimization Technique	Fisher's scoring

Figure 7. Logistic Model Response Profile (Cumulative Logit)

Ordered Value	Latent Status	Total Frequency
1 (Status 1)	1	13
2 (Status 2)	2	138
3 (Status 3)	3	944
4 (Status 4)	4	300
5 (Status 5)	5	70
6 (Status 6)	6	69

Notes:

- Number of Observations Read 1920
- Number of Observations Used 1534
- Probabilities modeled are cumulated over the lower Ordered Values.
- 386 observations were deleted due to missing values for the response or explanatory variables.
- Convergence criterion (GCONV=1E-8) satisfied.

Figure 8. Score Test for the Proportional Odds Assumption

Chi-Square	DF	Pr > ChiSq
851.8760	28	<.0001

Figure 9. Model Fit Statistics (Cumulative Logit)

Criterion	Intercept Only	Intercept and Covariates
AIC	3554.711	3450.205
SC	3581.389	3514.233
-2 Log L	3544.711	3426.205

Figure 10. Testing Global Null Hypothesis (Cumulative Logit; BETA = 0)

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	118.5053	7	<.0001
Score	115.7807	7	<.0001
Wald	112.1858	7	<.0001

Figure 11. Analysis of Maximum Likelihood Estimates (Cumulative Logit)

Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	*1*	1	-20.5856	5.9619	11.9224	0.0006
Intercept	*2*	1	-18.0373	5.9488	9.1937	0.0024
Intercept	*3*	1	-14.6758	5.9384	6.1076	0.0135
Intercept	*4*	1	-13.1947	5.9388	4.9363	0.0263
Intercept	*5*	1	-12.4498	5.9395	4.3936	0.0361
v001_rawvalue		1	0.000143	0.000080	3.2032	0.0735
v002_rawvalue		1	-0.7336	3.1189	0.0553	0.8140
v036_rawvalue		1	-0.2699	0.1730	2.4342	0.1187
v037_rawvalue		1	-0.3229	3.7208	0.0075	0.9308
v005_rawvalue		1	0.000120	0.000035	11.5990	0.0007
v147_rawvalue		1	0.2047	0.0679	9.0954	0.0026
v127_rawvalue		1	-0.00186	0.00258	0.5236	0.4693

Figure 12. Odds Ratio Estimates (Cumulative Logit)

Effect	Point Estimate	95% Wald Confidence Limits	
v001_rawvalue	1.000	1.000	1.000
v002_rawvalue	0.480	0.001	216.869
v036_rawvalue	0.763	0.544	1.072
v037_rawvalue	0.724	<0.001	>999.999
v005_rawvalue	1.000	1.000	1.000
v147_rawvalue	1.227	1.074	1.402
v127_rawvalue	0.998	0.993	1.003

Figure 13. Association of Predicted Probabilities and Observed Responses (Cumulative Logit)

Percent Concordant	63.8	Somers' D	0.287
Percent Discordant	35.1	Gamma	0.290
Percent Tied	1.0	Tau-a	0.164
Pairs	671573	c	0.643

Partial Proportional Odds Model

Figure 14. Generalized Logit Model Information

Model Information	
Data Set	TYPODATA.BASEMODEL_POST_REGRESS
Response Variable	Latent Status
Number of Response Levels	6
Model	generalized logit
Optimization Technique	Newton-Raphson

Figure 15. Logistic Model Response Profile (Generalized Logit)

Ordered Value	Latent Status	Total Frequency
1 (Status 1)	1	13
2 (Status 2)	2	138
3 (Status 3)	3	944
4 (Status 4)	4	300
5 (Status 5)	5	70
6 (Status 6)	6	69

Notes:

- Number of Observations Read 1920
- Number of Observations Used 1534
- Logits modeled use Latent Status = 6 as the reference category.
- 386 observations were deleted due to missing values for the response or explanatory variables.
- Convergence criterion (GCONV=1E-8) satisfied.

Figure 16. Model Fit Statistics (Generalized Logit)

Criterion	Intercept Only	Intercept and Covariates
AIC	3554.711	2905.077
SC	3581.389	3118.502
-2 Log L	3544.711	2825.077

Figure 17. Testing Global Null Hypothesis (Generalized Logit; BETA = 0)

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	719.6337	35	<.0001
Score	655.5097	35	<.0001
Wald	450.1696	35	<.0001

Figure 18. Type 3 Analysis of Effects (Generalized Logit)

Effect	DF	Wald Chi-Square	Pr > ChiSq
v001_rawvalue	5	25.3719	0.0001
v002_rawvalue	5	12.1839	0.0324
v036_rawvalue	5	70.3210	<.0001
v037_rawvalue	5	41.8042	<.0001
v005_rawvalue	5	55.6295	<.0001
v147_rawvalue	5	34.2212	<.0001
v127_rawvalue	5	32.1128	<.0001

Figure 19. Analysis of Maximum Likelihood Estimates (Generalized Logit)

Parameter	Latent Status	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	1	-10.1043	36.9344	0.0748	0.7844
Intercept	2	1	-44.8279	18.5609	5.8331	0.0157
Intercept	3	1	20.9309	17.1650	1.4869	0.2227
Intercept	4	1	9.1445	20.0658	0.2077	0.6486
Intercept	5	1	28.5419	23.1907	1.5147	0.2184
v001_rawvalue	1	1	-0.00070	0.000514	1.8350	0.1755

Parameter	Latent Status	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
v001_rawvalue	2	1	0.000277	0.000234	1.3982	0.2370
v001_rawvalue	3	1	0.000231	0.000203	1.3028	0.2537
v001_rawvalue	4	1	-0.00023	0.000221	1.1144	0.2911
v001_rawvalue	5	1	0.000634	0.000261	5.9220	0.0150
v002_rawvalue	1	1	19.2476	18.4921	1.0834	0.2979
v002_rawvalue	2	1	-14.8282	8.8901	2.7821	0.0953
v002_rawvalue	3	1	-5.7143	7.6014	0.5651	0.4522
v002_rawvalue	4	1	-17.7890	8.4290	4.4540	0.0348
v002_rawvalue	5	1	2.1731	10.3435	0.0441	0.8336
v036_rawvalue	1	1	-2.5196	1.2157	4.2950	0.0382
v036_rawvalue	2	1	1.7288	0.5181	11.1340	0.0008
v036_rawvalue	3	1	0.9216	0.4370	4.4470	0.0350
v036_rawvalue	4	1	2.9716	0.4941	36.1721	<.0001
v036_rawvalue	5	1	0.4139	0.5844	0.5015	0.4788
v037_rawvalue	1	1	42.8062	20.6870	4.2817	0.0385
v037_rawvalue	2	1	-11.2365	10.2702	1.1970	0.2739
v037_rawvalue	3	1	-35.4872	8.9228	15.8178	<.0001
v037_rawvalue	4	1	-14.7435	9.8244	2.2521	0.1334
v037_rawvalue	5	1	-45.4188	12.2826	13.6740	0.0002
v005_rawvalue	1	1	-0.00015	0.000226	0.4573	0.4989
v005_rawvalue	2	1	0.000180	0.000094	3.6557	0.0559
v005_rawvalue	3	1	-0.00021	0.000087	5.5682	0.0183
v005_rawvalue	4	1	-0.00024	0.000095	6.3851	0.0115
v005_rawvalue	5	1	-0.00036	0.000128	7.7455	0.0054
v147_rawvalue	1	1	0.1040	0.4235	0.0603	0.8060
v147_rawvalue	2	1	0.4856	0.2111	5.2915	0.0214
v147_rawvalue	3	1	-0.1713	0.1955	0.7680	0.3808
v147_rawvalue	4	1	-0.1861	0.2296	0.6572	0.4176
v147_rawvalue	5	1	-0.2715	0.2639	1.0586	0.3035
v127_rawvalue	1	1	0.0225	0.0125	3.2546	0.0712
v127_rawvalue	2	1	0.00305	0.00762	0.1601	0.6890
v127_rawvalue	3	1	-0.0144	0.00672	4.5826	0.0323

Parameter	Latent Status	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
v127_rawvalue	4	1	0.00405	0.00727	0.3101	0.5776
v127_rawvalue	5	1	-0.0238	0.00930	6.5363	0.0106

Figure 20. Odds Ratio Estimates (Generalized Logit)

Effect	Latent Status	Point Estimate	95% Wald Confidence Limits	
v001_rawvalue	1	0.999	0.998	1.000
v001_rawvalue	2	1.000	1.000	1.001
v001_rawvalue	3	1.000	1.000	1.001
v001_rawvalue	4	1.000	0.999	1.000
v001_rawvalue	5	1.001	1.000	1.001
v002_rawvalue	1	>999.999	<0.001	>999.999
v002_rawvalue	2	<0.001	<0.001	13.411
v002_rawvalue	3	0.003	<0.001	>999.999
v002_rawvalue	4	<0.001	<0.001	0.281
v002_rawvalue	5	8.785	<0.001	>999.999
v036_rawvalue	1	0.080	0.007	0.872
v036_rawvalue	2	5.634	2.041	15.554
v036_rawvalue	3	2.513	1.067	5.919
v036_rawvalue	4	19.523	7.413	51.418
v036_rawvalue	5	1.513	0.481	4.756
v037_rawvalue	1	>999.999	9.588	>999.999
v037_rawvalue	2	<0.001	<0.001	>999.999
v037_rawvalue	3	<0.001	<0.001	<0.001
v037_rawvalue	4	<0.001	<0.001	91.100
v037_rawvalue	5	<0.001	<0.001	<0.001
v005_rawvalue	1	1.000	0.999	1.000
v005_rawvalue	2	1.000	1.000	1.000
v005_rawvalue	3	1.000	1.000	1.000
v005_rawvalue	4	1.000	1.000	1.000
v005_rawvalue	5	1.000	0.999	1.000
v147_rawvalue	1	1.110	0.484	2.545

Effect	Latent Status	Point Estimate	95% Wald Confidence Limits	
v147_rawvalue	2	1.625	1.074	2.458
v147_rawvalue	3	0.843	0.574	1.236
v147_rawvalue	4	0.830	0.529	1.302
v147_rawvalue	5	0.762	0.454	1.279
v127_rawvalue	1	1.023	0.998	1.048
v127_rawvalue	2	1.003	0.988	1.018
v127_rawvalue	3	0.986	0.973	0.999
v127_rawvalue	4	1.004	0.990	1.018
v127_rawvalue	5	0.977	0.959	0.994

Appendix K – References

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